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THE DEVELOPMENT OF THE JULY 1989 1° X 1° AND 30′ X 30′ TERRESTRIAL MEAN FREE-AIR ANOMALY DATA BASES

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by

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(NASA-CR-186475) THE DEVELOPMENT OF THE JULY 1989 1 DEG X 1 DEG AND 30' X 30' TERRESTRIAL MEAN FREE-AIR ANOMALY DATA BASES (Ohio State Univ.) 103 p CSCL 04A

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Abstract

In June 1986 a 1° x 1° mean free-air anomaly data file containing 48955 anomalies was completed. In August 1986 a 30′ x 30′ mean free-air anomaly file was defined containing 31787 values. For the past three years data has been collected to upgrade these mean anomaly files. The primary emphasis was the collection of data to be used for the estimation of 30′ mean anomalies in land areas. The emphasis on land areas was due to the anticipated use of 30′ anomalies derived from satellite altimeter data in the ocean areas.

There were 10 data sources in the August 1986 file. Twenty-eight sources were added based on the collection of both point and mean anomalies from a number of individuals and organizations. A preliminary 30′ file was constructed from the 38 data sources. This file was used to calculate 1° x 1° mean anomalies. This 1° x 1° file was merged with a 1° x 1° file which was a merger of the June 1986 file plus a 1° x 1° file made available by DMA Aerospace Center. Certain bad 30′ anomalies were identified and deleted from the preliminary 30′ file leading to the final 30′ file (the July 1989 30′ file) with 66990 anomalies and their accuracy. These anomalies were used to again compute 1° x 1° anomalies which were merged with the previous June 86 DMAAC data file. The final 1° x 1° mean anomaly file (the July 89 1° x 1° data base) contained 50793 anomalies and their accuracy.

The anomaly data files were significantly improved over the prior data sets in the following geographic regions: Africa, Scandinavia, Canada, United States, Mexico, Central and South America. Substantial land areas remain where there is little or no available data.

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Foreword

This report was prepared by Jeong-Hee Kim, Graduate Research Associate, and Richard H. Rapp, Professor, Department of Geodetic Science and Surveying. The research described in this report is supported by NASA Grant NGR36-008-161, The Ohio State University Research Foundation Project 783210. The grant covering this research is administered through the NASA Goddard Space Flight Center, Greenbelt, MD 20771.

Acknowledgments

Many persons and organizations contributed information presented in this report. The first group provided data to be used in this analysis. Without these significant contributions little improvement over our previous data bases would have been possible. Some of the data used in this new update was kindly provided by the following: C. Aiken, D. Sölheim, R. Forsberg, C.C. Tscherning, D. Arabelos, R. Chang, D. Fairhead (for the African Gravity Project), J. Adam, A. Mainville, G. Balmino, D. Blitzkow, C. Merry, W. Kearsley, P. Kletas, A. Watts, C. Liu, A. Lwangasi, K. Choi, J. Segawa, S. Gerrard, and the Defense Mapping Agency Aerospace Center.

The analysis of this data has been carried out by numerous persons in the past three years. The starting framework was provided by V. Despotakis with the 1986 updates and continuing activities after that. Other persons playing a significant role in the analysis of various sources were G. Priovolos, L. Tsaoussi, and N. Pavlis. Without the contributions from these persons over the past three years the update described in this report could not have been done.

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1. Introduction

Numerous computations in gravimetric geodesy require knowledge of mean gravity anomalies. These anomalies are usually defined in equi-angular cells such as 1° x 1°, 30′ x 30′, 10′ x 10′, etc. The collection and evaluation of 1° x 1° mean anomalies at The Ohio State University have been carried out since 1972. This collection has been primarily based on anomalies collected by the Defense Mapping Agency Aerospace Center augmented by data collected at Ohio State. The result of this work has been a set of 1° x 1° data files that were made available at an approximate interval of three years. The last update took place in 1986 resulting in the June 1986 1° x 1° anomaly set (Despotakis, 1986). The number of anomalies in the 1° x 1° data bases developed over the years is given in Table 1. This count includes geophysically predicted anomalies (about 6000 values) as well as the number of anomalies being described in this update.

Table 1

Number of 1° x 1° Anomalies in Data Sets Developed at The Ohio State University

Date	Number of Anomalies
June 72	23355
Sept 73	29789
July 75	36149
Aug 76	38406
June 78	39405
Oct 79	41973
Jan 83	44513
June 86	48955
July 89	50793

It should be noted that not only the number of data values has increased but the quality of the values has become better through more rigorous quality control and improved estimation procedures.

In 1985 it became clear that there was a need for 30′ x 30′ mean anomalies. These values could be used for the verification of altimeter derived anomalies, and in the determination of higher degree spherical harmonic expansions. The latter reason was the primary driver for the data collection so that the original emphasis was on the collection of data in land areas. The first 30′ data set (August 1986), based only on terrestrial gravity measurements, contained 31787 values. In the development to be described in this paper, the number of anomalies in the final (July 89) data file is 66990. The file represents not only an increase of 35203 over the August 1986 file, but also a substantial increase in quality through the updating of values that did exist in the 1986 file.

This report describes the various sources used in these new updates as well as the analysis that was carried out that led to the final data sets. Some aspects of this report relate to internal procedures and documentation of software, while other aspects relate to the collection and analysis process.

In the 1986 30′ update data source numbers were assigned sequentially from 1. To improve our distinction between 1° sources and 30′ sources the 30′ source numbering scheme was altered for this new update. Specifically all 30′ sources would be numbered starting from 1001. A correspondence between the August 86 source and the July 89 sources will be described later in this report.

2. The Development of the July 1989 30′ Anomaly Data Set - Introduction

There have been as many as 15 intermediate updates since the August 86 update. This is seen through the files written on the tape GS 327, the master tape of the OSU 30′ free-air anomaly field. Fifteen new files had been written since the August 86 update. The first 3 updates (files 5, 6, 7) were done by Priovolis. The next 2 updates (files 8 and 9) were done by Despotakis. However, these 5 updates were not sequentially used in the rest of updates. File 10 of tape GS 327 was created by Pavlis after merging the final file of the August 86 update (file 4) with the TUG '87 30′ elevations (file 2, GS 367), and this file was sequentially used in the rest of the updates.

In the next 5 updates, each had new sources added to the previously existing files as follows;

File Number of Tape GS327	New Sources Added
11	S1011 to S1021
12	S1022 to S1025
13	S1026 to S1031
14	S1027, S1032, S1033, S1034, S1036
15	S1035, S1037, S1038

S1027 was introduced both in the file 13 and in file 14 due to an input error.

The next 4 updates proceeded as follows:

File Number of Tape GS 327	What's Done
16	• Adding 1000 to the source I.D. of 30′ sources
17	• deleting 2 values of S1018 and changing 12 values of S1002
18	• deleting values of problem blocks
19	• deleting values of problem blocks

Details will be discussed in subsequent sections.

For the areas where we did not have any terrestrial data before, the new values are accepted. However, if we have overlaps between the August 86 field and new sources and/or among new sources, one must choose one value over another. This selection procedure is described in the next sections. In Section 2.1, the standard procedures and the human choices are discussed and in the next, all the individual decisions on each source are represented.

2.1 Selection Procedures

2.1.1 Criteria of Choosing One Anomaly Over Another in a Block and its Standard Deviation

The selection criteria used for the 30′ x 30′ block mean anomalies are the same as used for the one degree anomaly update in the June '86 field. These criteria are found in the report by Despotakis (1986) in section 2.0 and they are used in the selecting program F292K (The program numbers refer to programs as the software library of Rapp.)

There are three data sets to be considered in the anomaly selection process. These data sets will be an existing file of terrestrial data, the file of anomalies derived from satellite altimeter data, and the new anomaly value (or file). With this data, numerous criteria have been implemented that lead to the selection of an anomaly and its standard deviation. These criteria are described below:

1. If an altimeter derived anomaly is not available (e.g. a land anomaly), or the accuracy of an available anomaly is ≥ 10 mgals, the terrestrial estimate (existing or new) with the smallest standard deviation is accepted.

2. If an altimeter derived anomaly is available with an accuracy < 10 mgals, there are two situations:

   a. The value with the smaller standard deviation is accepted if |old-new anomaly| is < 5 mgal.

   b. The value closer to the altimeter derived anomaly is accepted if |old-new anomaly| ≥ 5 mgal. In this case the standard deviation of the selected value may be modified as follows:

      Case 1. If |old-altimeter value|/2 is greater than the standard deviation of the old anomaly when the old anomaly is accepted, the modified standard deviation is INT (standard deviation of the old anomaly + |old - new|/20 + 0.5), where INT indicates the integer value.

      Case 2. If |new - altimeter value|/2 is greater than the standard deviation of the new value when the new value is accepted, the modified standard deviation is INT (standard deviation of the new anomaly + |old - new|/20 + 0.5).

It should be pointed out that the altimeter derived anomalies and their standard deviations are used for reference and/or comparison purposes. These values are not accepted or modified in any way for the final selected value. The anomaly standard deviations for sources S1001 to S1010 were determined through several different procedures described in Despotakis (1986). For this update the following empirical formula was used to assign an accuracy estimate (σ) of a 30′ anomaly:

$$\sigma = \text{Max}\left\{2, \text{INT}\left(25/\sqrt{n} + 0.05 * \left|\Delta g\right| + 0.5\right)\right\} \tag{1}$$

where n is the number of point anomaly values, or "sub" mean anomalies that exist in the 30′ block. Δg is the 30′ free-air mean anomaly.

The reliability of this formula is greatly effected by the distribution of point values in the cell. To minimize this problem, 'the thinning method' is used if applicable and necessary. It is the method in which we divide 30′ blocks into smaller blocks (5′ or 2′ blocks) and pick a value in each block and average them to get the 30′ mean anomaly and finally give the n value as the number of those smaller blocks available within a 30′ block for calculating standard deviations.

If the new sources is an anomaly contour map, or a set of tabulated values, a case by case accuracy consideration is given. Typically a 30′ accuracy of 10 mgals is given in these cases.

2.2 "Human Choice" Selection Methods

The standard criteria described in the previous section are based on the assumption that the altimeter data are reliable, and standard deviations of the old and new sources are comparable to each other. However, not all the altimeter data are reliable (for example, values near or on the shore) and the standard deviation of the terrestrial data were estimated in different ways so that they may not be comparable though the best efforts were made.

Furthermore, certain data sets are believed to be more reliable than others irrespective of their accuracies. For example, for the same area, if the same organization sends a new data set, it is reasonable to believe that the new data are better than the old. In such a case, we may accept the entire values of one particular source over others. This human choice can be coded directly in the F292K program.

Another kind of human choice may be necessary when large discrepancies among different sources are observed. As we see in the standard procedures, we may let the F292K program choose the proper values if reliable altimeter values are available. However, if altimeter data are not available, or they are supposed to be reliable according to their standard deviation but suspicious due to large discrepancies with other source values, it should be prudent to use some other data listings such as BGI (1988), Watts et al (1985), etc. to help make selection decisions. Actual cases are discussed in the next section. This human choice can be hardly coded in the F292K program and direct modifications on the output files of the F292K run are to be made.

3. New Sources and Data Processing

This section is concentrated on the description of each source, such as the nature (point values?, free-air anomalies?), origin (who sent them?), estimation of 30′ mean free-air anomalies and their accuracies, distributions (geographical coverage), location (where existing), etc. The description of sources 1001 to 1010 may be found in Despotakis (1986) recalling that the source numbers in Despotakis are 1000 less than the source numbers used here.

3.1 Source 1011

Source 1011 was based on the 4 km x 4 km gridded data base established by the Society of Exploration Geophysicists in 1982. O'Hara and Lyons (1985) discuss the gravity anomaly map of the United States that was produced from this, primarily Bouguer anomaly, data set. The preparation of the gridded data base is discussed by Godson (1985). Godson and Scheibe (1983) prepared a gridded free-air anomaly file based on the data set used for the Bouguer anomaly file. Rapp and Zhao (1988) describe the conversion of this gridded free-air anomaly file to a latitude/longitude based system. It is this file that is source 1011. The file is stored on file 2 of tape GS383. The anomalies were given with respect to the gravity formula of the Geodetic Reference System 1967. 4973 30′ mean anomalies were calculated by averaging all gridded point values in the cell. The mean anomaly accuracy estimate was based on the number of points used in the calculation of the mean value using the rule of thumb described earlier (eq. 1). The location of the 30′ mean values available from this source is shown in Figure 1.

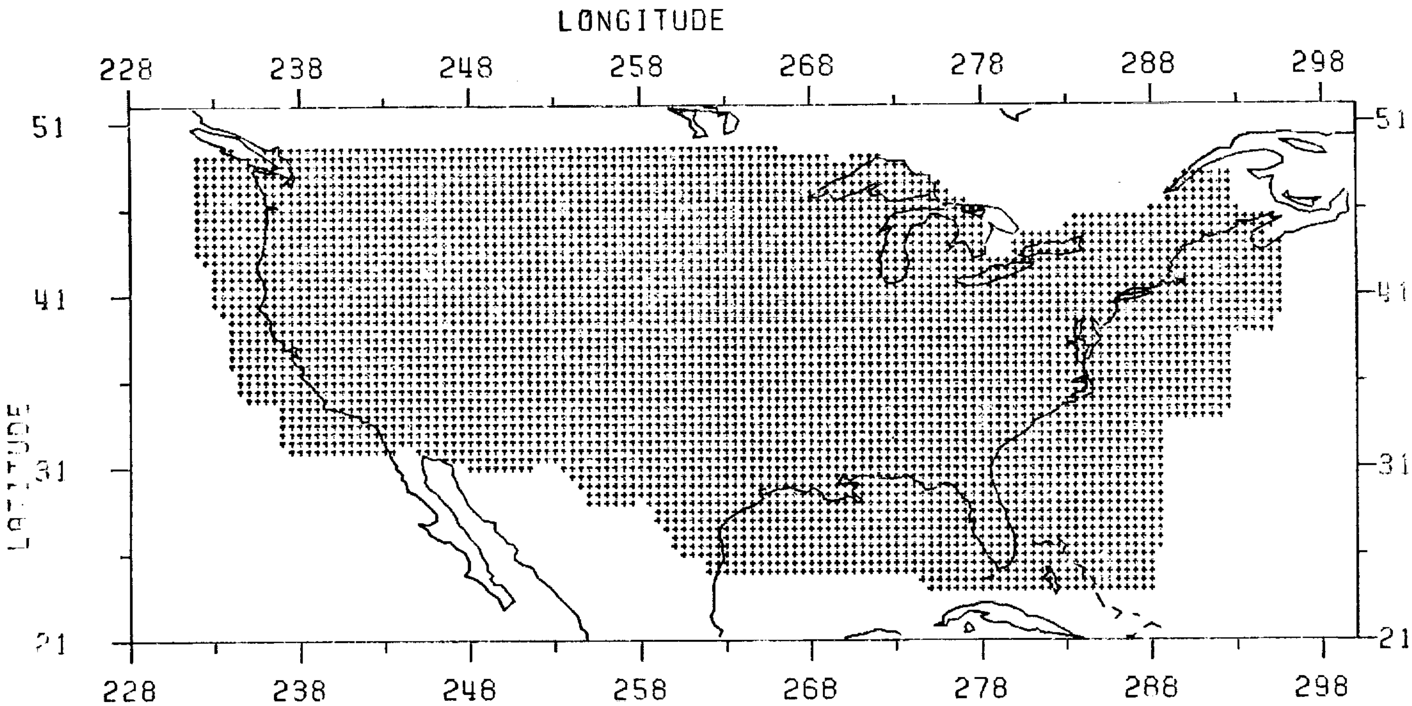

Figure 1. Location of 4973 30′ Mean Anomalies from Source 1011

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3.2 Source 1012

Source 1012 is a 10 km x 10 km grid of Bouguer gravity anomalies in Australia. The grid was computed by Zuber and transmitted to Ohio State in September 1987. The data is stored on file 2 of tape AGRAV2.

3220 30′ mean Bouguer anomalies were computed by averaging the point values that fell within the 30′ cell. These mean anomalies were converted to 30′ mean anomalies using the following equation.

$$\Delta g_f = \Delta g_b + 0.1119\,h \tag{2}$$

where Δg_f is the free-air anomaly (mgal)
Δg_b is the Bouguer anomaly (mgal)
h is the TUG 87 (Wiser, 1987) 30′ mean elevation in meters from tape GS367.

Note that equation (2) uses the crustal density of 2670 kg m^{-3} as used by Zuber.

The gravity values are referred to the old Potsdam gravity base station system and to the gravity formula of the Geodetic Reference System 1967. To convert to the IGSN71 absolute system the 14 mgal Potsdam system was applied.

$$\Delta g_f^* = \Delta g_f - 14.0 \text{ mgal} \tag{3}$$

where: Δg_f^* is the anomaly referred to GRS67, and Δg_f is the anomaly referred to IGSN71.
The distribution of the 30′ mean free-air anomalies is shown in Figure 2.

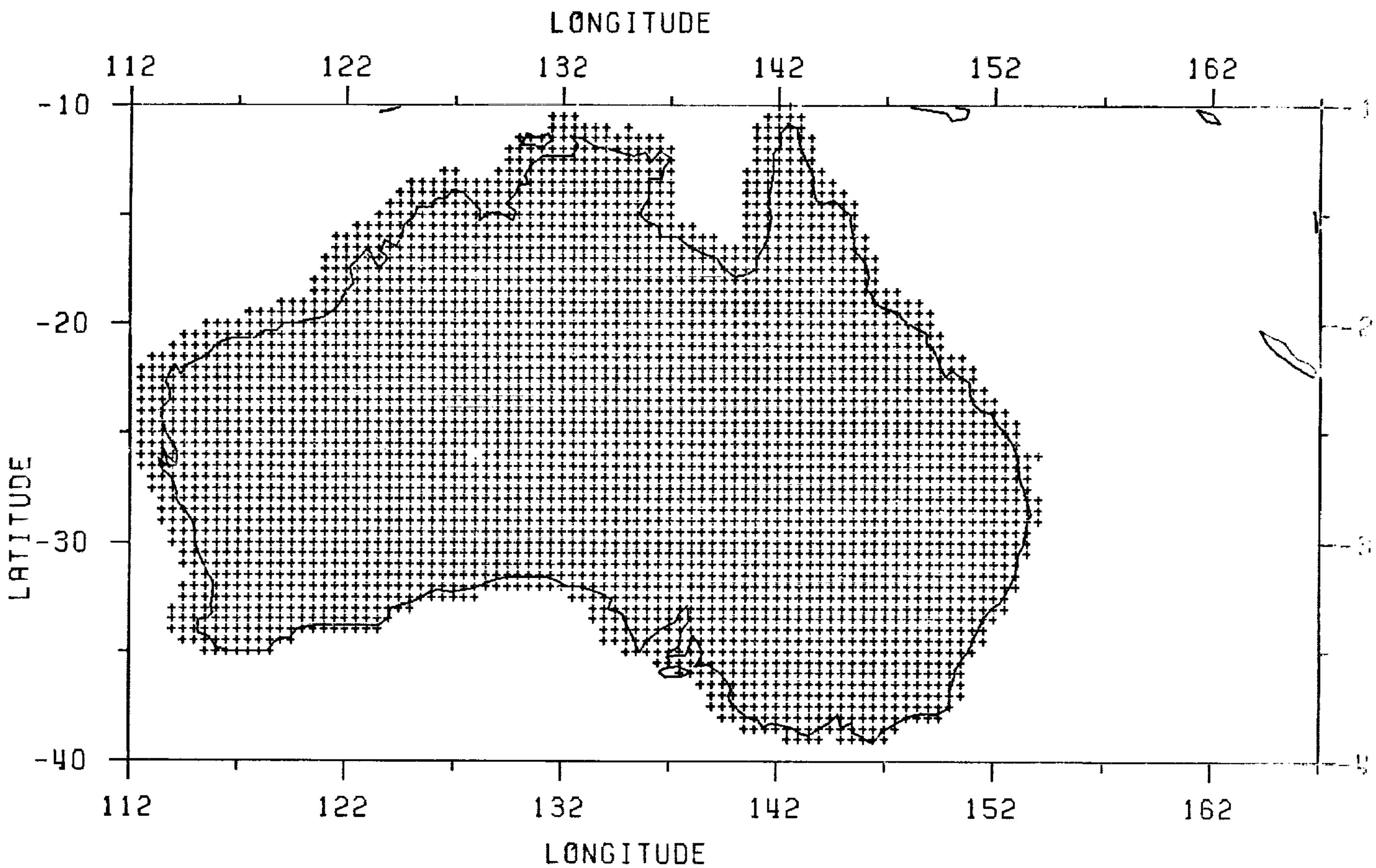

Figure 2. Location of 3220 30′ Anomalies in Source 1012

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3.3 Source 1013

This source contains 5427 point free-air anomalies in Brazil sent by Icanhower, letter dated 05/10/88, on tape SL045, based on data originally provided by Blitzkow. The anomaly values refer to the gravity formula of WGS 84 with atmospheric corrections. They were transformed to the gravity formula of GRS 67 with the atmospheric correction removed by the following formulas (DMAAC, 1987):

$$\Delta g_{GRS67} = \Delta g_{WGS84} - \delta g_A - \delta_\gamma \tag{4}$$

where:

$$\delta g_A = 0.87 \cdot \mathrm{EXP}\left(-0.116 \cdot H^{1.047}\right) \text{ mgal}$$

with H the elevation of the point in km.

$$\delta_\gamma = -0.8271 - 0.1475\sin^2\phi + 0.1860\sin^4\phi$$
$$-0.1234\sin^6\phi - 0.0007\sin^8\phi, \text{ mgal}$$

(ϕ is the latitude of the point)

The transformed point values were averaged to form 147 30′ mean free-air anomalies. Standard deviations were calculated from equation (1). The distribution of the point anomalies is shown in Figure 3.

3.4 Source 1014

This source contains 5633 5′ x 6.25′ mean free-air anomalies in Greece sent by Kletsas in a letter dated 5/18/88 in the tape S001. The values are referred to the Potsdam gravity system and the International Gravity Formula. They were transformed to the GRS 67 using the following:

$$\Delta g_{GRS67} = \Delta g_{1930} + 3.2 - 13.6\sin^2\phi \text{ (mgal)}. \quad (5)$$

The resulting mean values were averaged to form 225 30′ mean anomalies and accuracies were estimated with equation (1) where n is the number of 5′ x 6.25′ mean values in the 30′ cell. The distribution of the 5′ x 6.25′ mean values is shown in Figure 4.

3.5 Source 1015

This source contains 35 30′ mean free-air and Bouguer anomalies in Zambia sent by Barringer Geoservices, Golden Colorado, on behalf of Placid Oil Company, Dallas, Texas, in an IBM floppy disk. The reference gravity formula and standardization network are not known. Additional data (S1016) were received that led to the exclusion of anomalies in this source from the final update.

3.6 Source 1016

This source contains 53852 $0.^\circ 25$ x $0.^\circ 25$ mean free-air anomalies in Madagascar and surrounding area as sent by Balmino, in letter dated 10/03/86 in the tape JALES2. Values were averaged to form 3108 30′ mean free-air anomalies excluding the ocean blocks as they were computed from SEASAT data (Rakotoary, 1986).

Since the source values are referred to the GRS80 gravity formula, the 30′ values were transformed to the GRS67 formula as follows:

$$\Delta g_{GRS67} = \Delta g_{GRS80} + 0.83 + 0.0782\sin^2\phi \text{ (mgal)} \quad (6)$$

Accuracies were estimated by equation (1). The distribution of the $0.^\circ 25$ x $0.^\circ 25$ mean values including sea block values is shown in Figure 5.

3.7 Source 1017

This source contains 686 point free-air and Bouguer anomalies in the North-West peninsula of Malaysia. This source is discussed by Omar (1986).

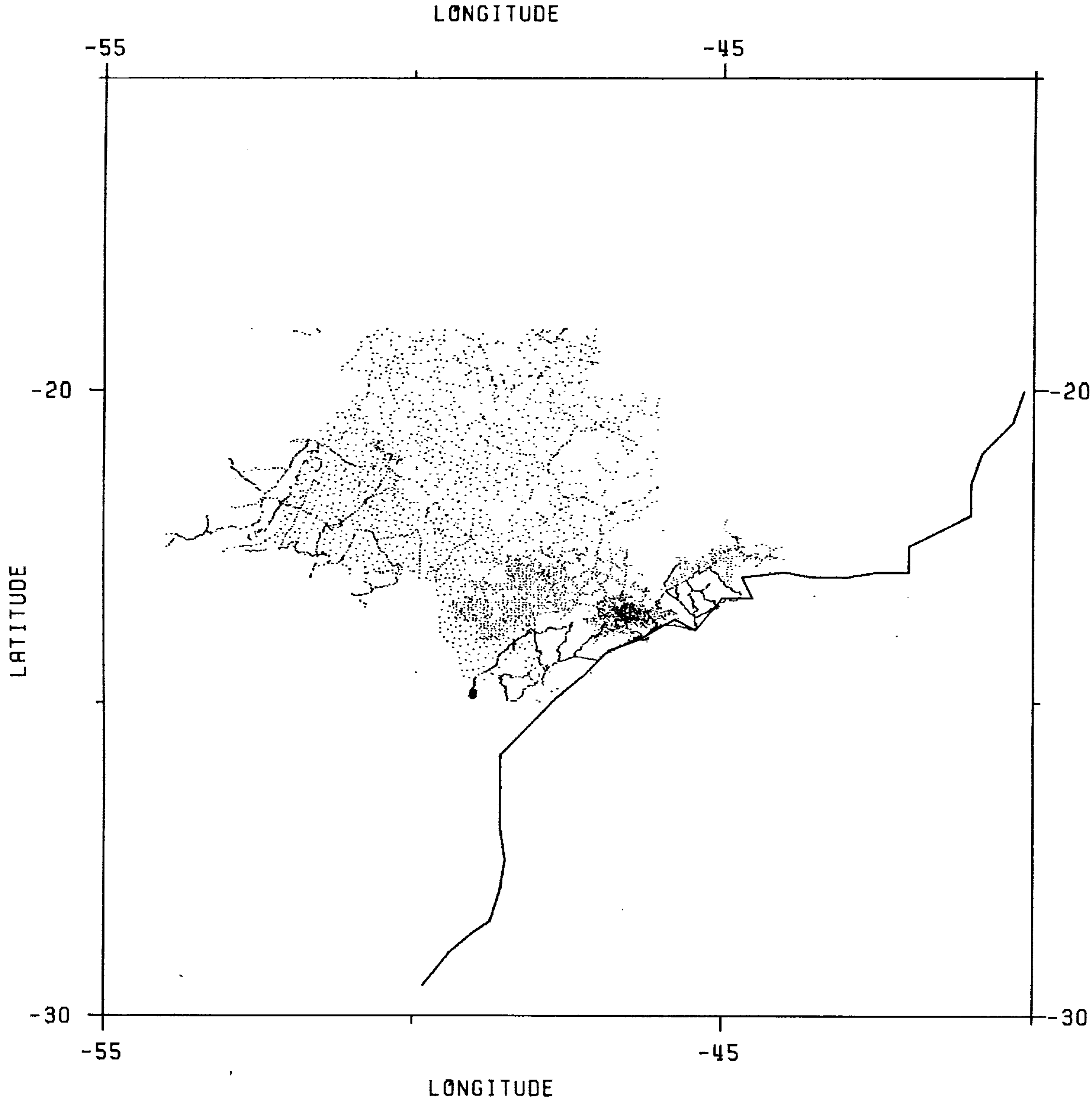

Figure 3. Location of 5427 Point Anomalies from Source 1013

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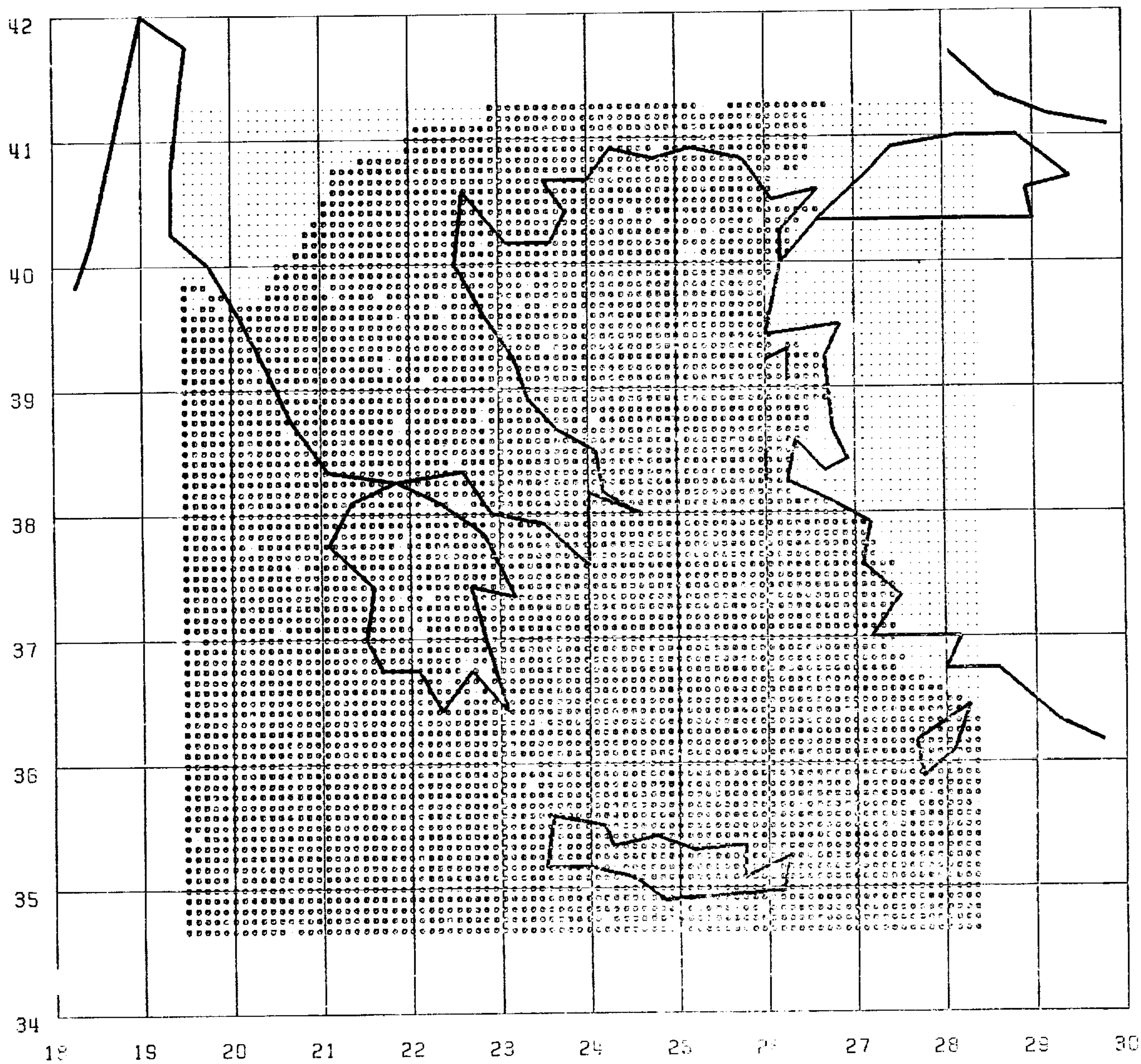

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Figure 4. Location of 5633 5′ x 6.′25 Anomalies from Source 1014

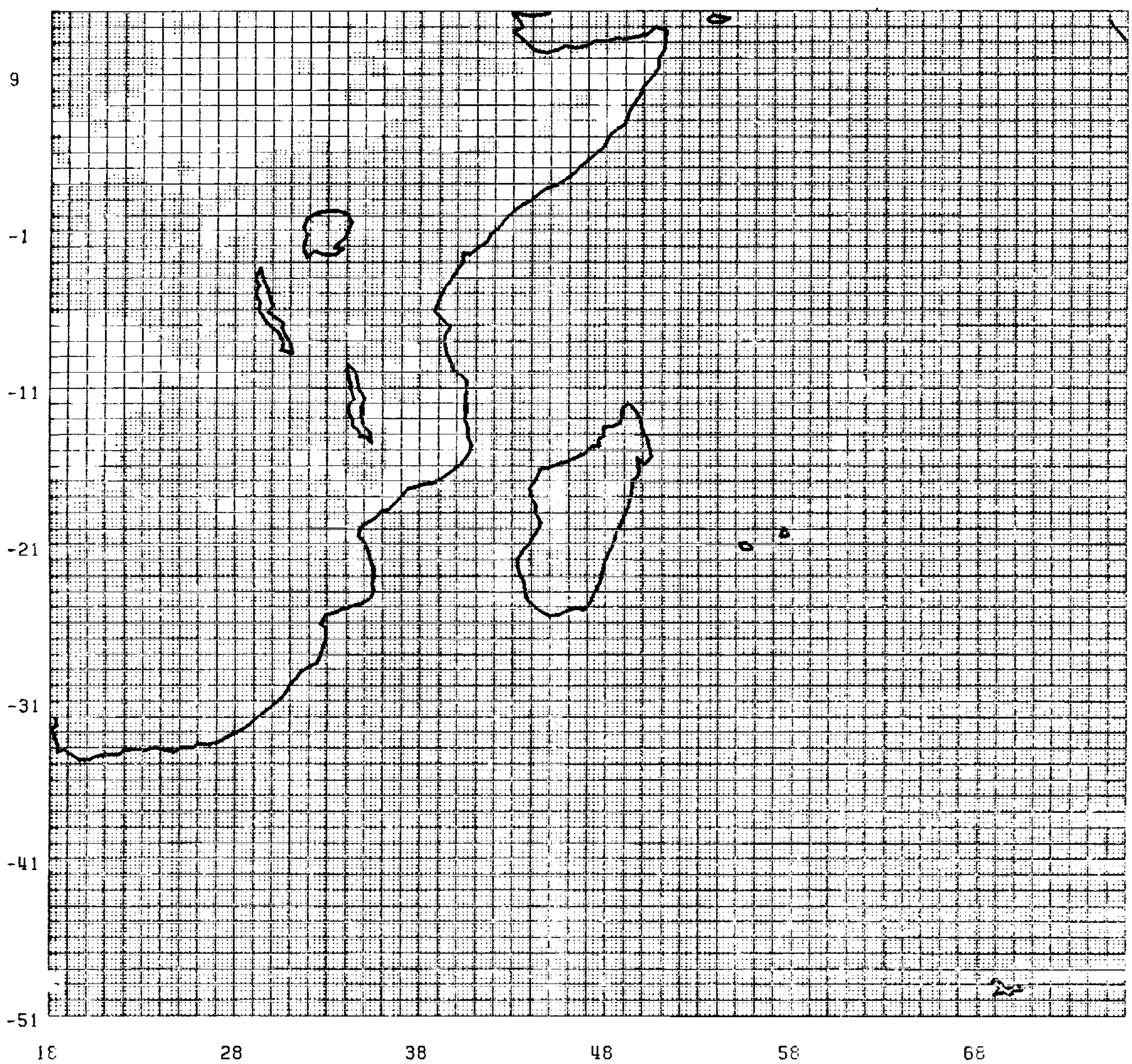

Figure 5. Location of 53852 0°.25 x 0°.25 Anomalies in Source 1016

The original values were referred to the gravity formula of GRS80 so that they were transformed to GRS67 using equation (6). They were then averaged to form 17 30′ mean free-air anomalies and stored in OSU ASM2 tape under DSN = TS0453.PMDATA. The accuracies were estimated from equation (1).

3.8 Source 1018

This source contains 25937 point free-air anomalies in the Hawaiian Island area sent by Watts, in a letter dated 4/16/87, (tapes WATTSS1, WATTSS2), and 715 point free-air and Bouguer anomalies in the same region stored in the tape GS202 sent by the National Geodetic Survey (NGS) in 1983.

The Watts and NGS values were separately averaged to form 273 and 20 (respectively) 30′ mean values. The accuracies were estimated from equation (1). The WATTS's 30′ values were then called S1018W. The 30′ free-air anomalies (from averaging NGS point free-air anomalies), and free-air anomalies computed from NGS point Bouguer anomalies with TUG87 elevations were then called S1018WF and S1018NB, respectively.

The distribution of the NGS and the Watts point values are shown in Figure 6 and 7 respectively.

3.9 Source 1019

This source contains 145201 point free-air anomalies in Alaska sent by NGS in 1983 and stored on tape GS202. The values were averaged to form 1467 30′ mean values with the accuracies estimated by equation (1). The distribution of the point anomalies is shown in Figure 8.

3.10 Source 1020

This source contains 15731 point free-air anomalies in Bermuda sent by NGS, in 1983, and stored on tape GS202. The values were averaged to form 27 30′ mean values and accuracies were estimated using equation (1).

3.11 Source 1021

This source is based on 588009 point free-air anomalies in Canada sent (6/29/88) by Mainville. The data are on tapes GDC142 and GDC143. The values were averaged to form 12637 30′ mean values after combining values in both tapes. Then, 647 30′ mean values which are not common with S1011, S1019 and S1036 were adopted as S1021. The accuracies were estimated by equation (1).

The distribution of the point values of GDC142 (264614 values) and GDC 143 (323395 values) are shown in Figure 9-A and 9-B respectively. Figure 10 shows the locations of the 647 30′ values.

3.12 Source 1022

This source contains 2601 30′ mean free-air anomalies in the tape MTRHRO and 3414 30′ mean free-air anomalies in the tape MTRHRN for Scandinavian area sent by Sölheim, letter dated 11/18/88 and 01/13/89. This source contained mean anomalies estimated from the data and values interpolated from the mean values.

The values for the common blocks from the two tapes were found to be identical and data on both tapes were merged by Pavlis to form one file, TS0040.SCANDIA containing 3414 30′ values. They are referred to the gravity formula of GRS 80 and converted to the GRS67 gravity formula as follows (Pavlis, 1988):

$$\Delta g_{GRS67} = \Delta g_{GRS80} + \delta g \tag{7}$$

where:

$$\delta g = d_0 + d_2 \sin^2\phi + d_4 \sin^4\phi$$

$$d_0 = \gamma_{e\,GRS80} - \gamma_{e\,GRS67}$$

$$d_2 = a_{2\,GRS80} - a_{2\,GRS67}$$

$$d_4 = a_{4\,GRS80} - a_{4\,GRS67}$$

The values of d_0, d_2, d_4 are given in Pavlis (ibid, p. 61).

The resulting file is TS0040.SCANDIA.ANOM.MIN30X30.GRS67. No information on the number of points, or on the anomaly accuracy was available. However, we assigned an empirical standard deviation of 5 mgal or 15 mgal to the values calculated by observation or by interpolation respectively. The distribution of the 30′ mean values is shown in Figure 11.

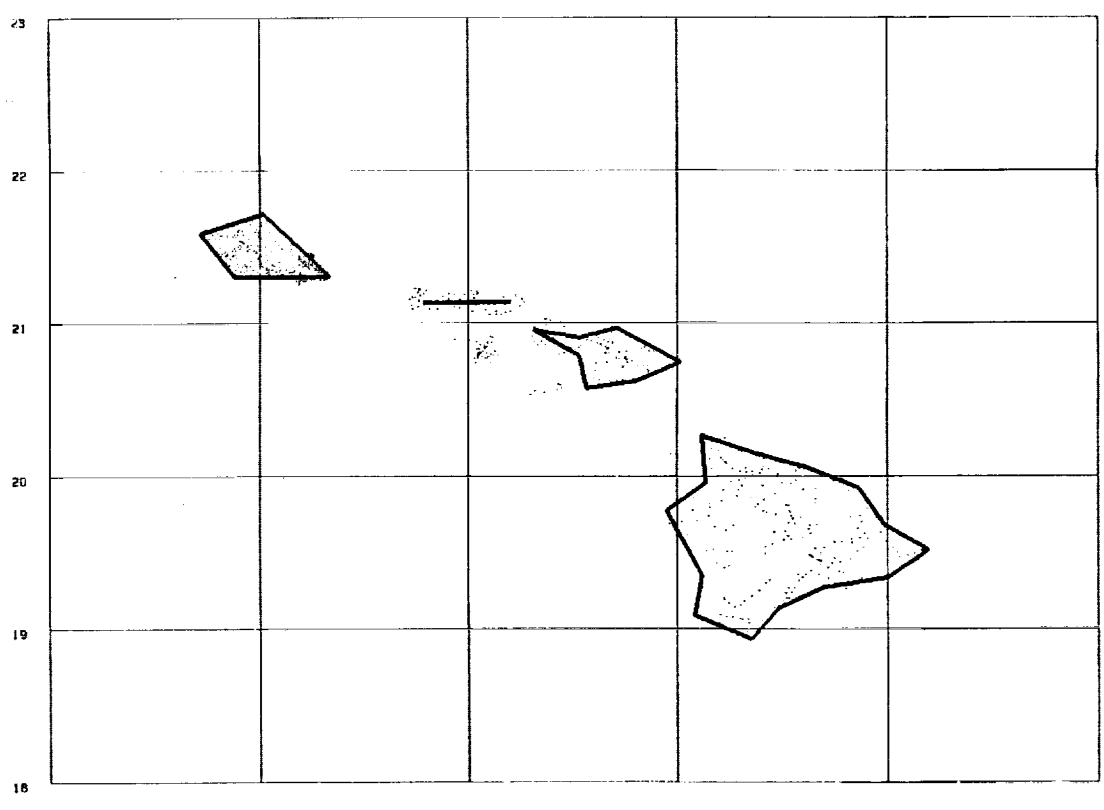

Figure 6. Distribution of 715 Point Anomaly Data from the National Geodetic Survey in the Hawaiian Island Area

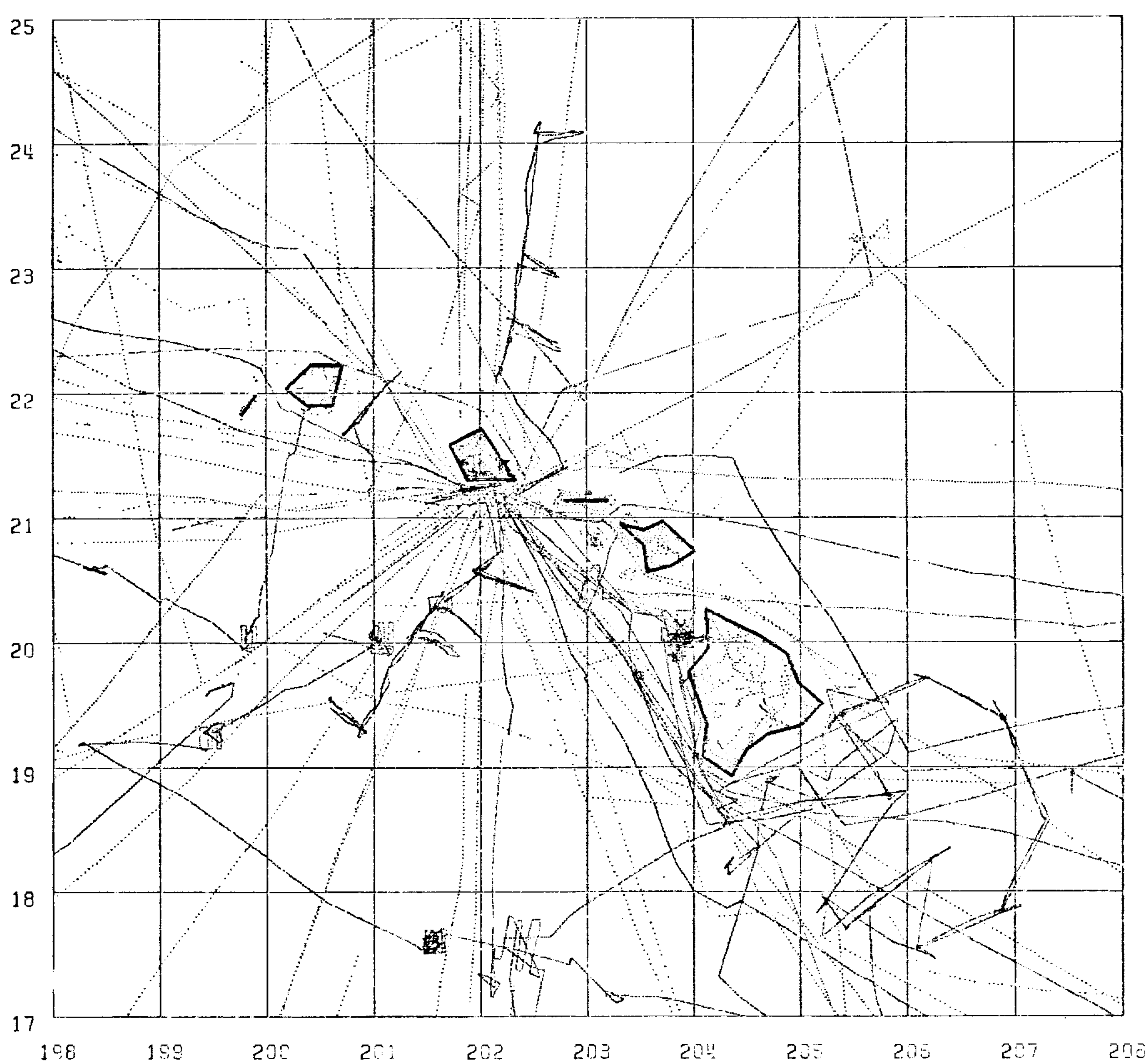

Figure 7. Distribution of 25937 Point Anomaly Data from Watts in the Hawaiian Island Area

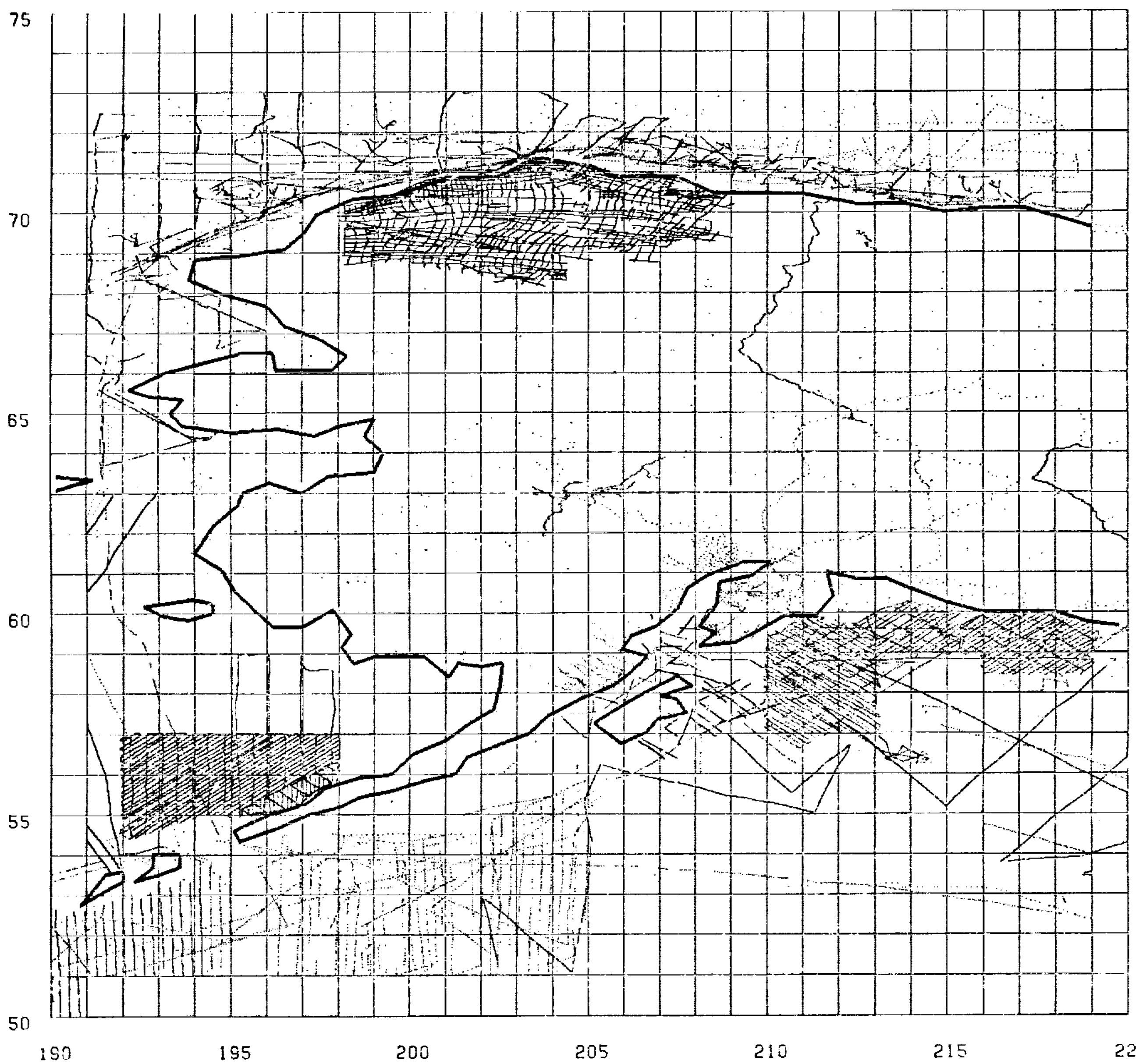

Figure 8. The Distribution of 145201 Point Anomalies from Source 1019

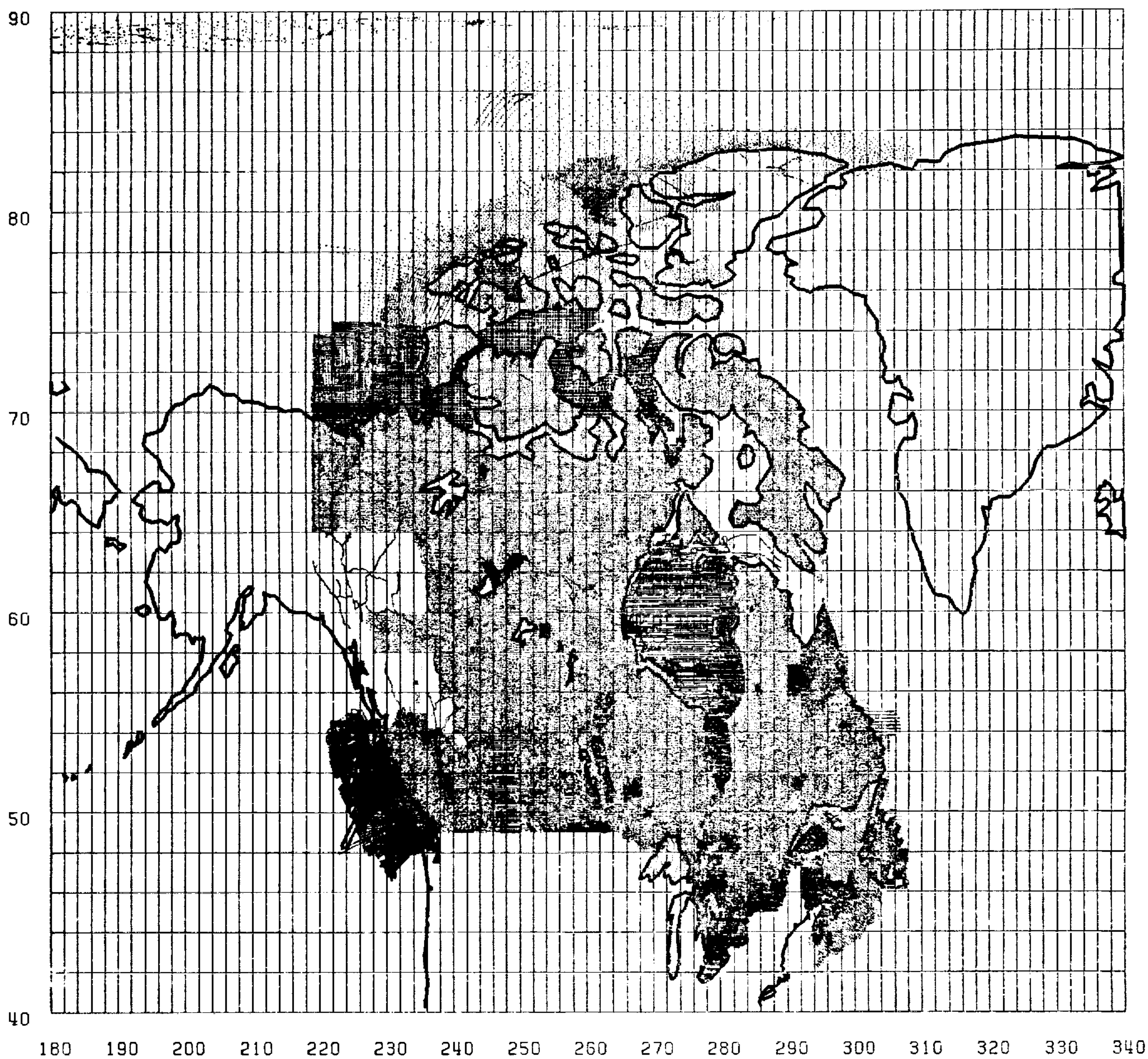

Figure 9-A. Location of 264614 Point Anomalies on Tape GDC142

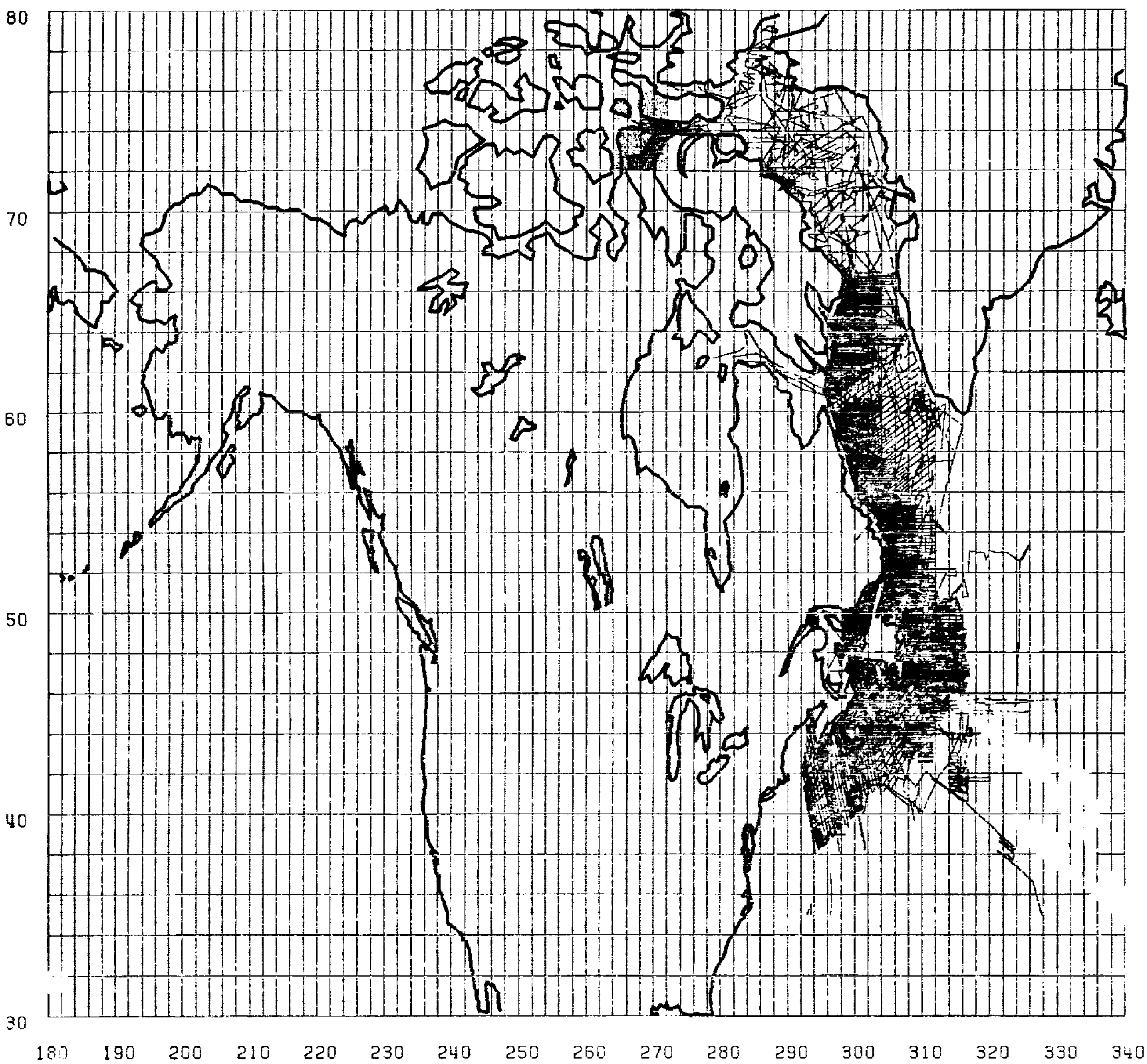

Figure 9-B. Location of 323395 Point Anomalies on Tape GDC143

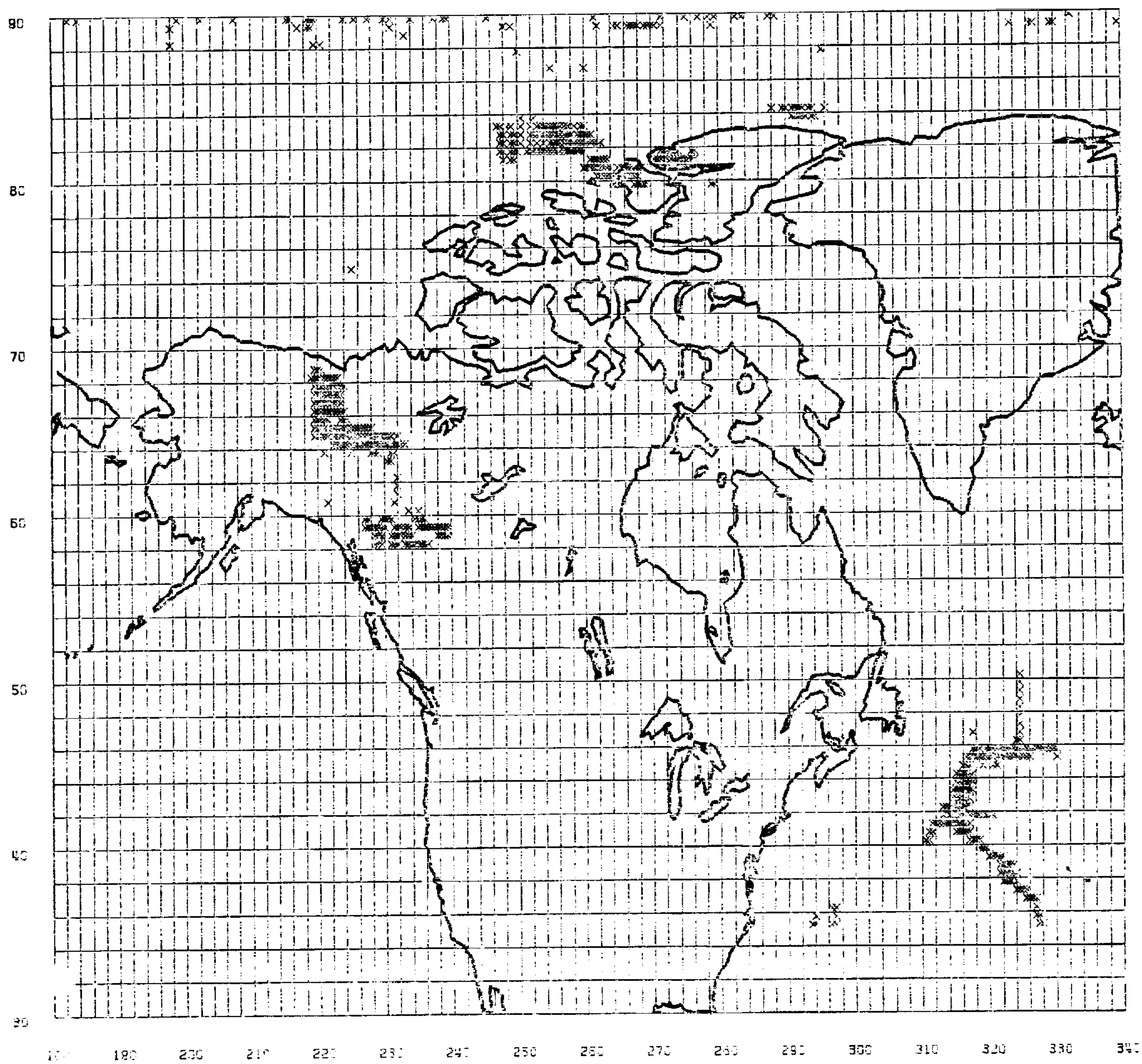

Figure 10. Location of 647 30′ Anomalies from Source 1021

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3.13 Source 1023

This source is based on 117 10′ x 10′ mean free-air anomalies in Taiwan sent by Chang in a map, October 1988 and a free-air anomaly map of Taiwan sent by Liu, February 1989. The former values were averaged to form 30′ mean values and accuracies in 10′ blocks were estimated to be 5 to 16 mgal depending on the roughness of terrain as found in Chang (1988). Map estimations on the latter data were made by dividing a 30′ block into 9 smaller blocks and averaging visually. The standard deviations were assigned to be 5 ~ 20 mgals depending on the roughness of the anomaly field. Analysis of the values from each map was made to obtain the final values as discussed in Section 4.6.1.

3.14 Source 1024

This source is 198 30′ mean free-air anomalies in Kenya sent by Lwangasi, in a letter dated 11/14/88, in 4 tabulated maps. The accuracies were estimated by equation (1) based on the number of points used to determine the mean anomalies.

3.15 Source 1025

This source contains 508 point free-air anomalies in Hungary made available by Adam in a floppy disk based on data given by Renner (1959). The values were averaged to form 30′ mean free-air anomalies and they were converted from the Potsdam reference system to the gravity formula of GRS67 using formula (5) and the accuracies were estimated by equation (1).

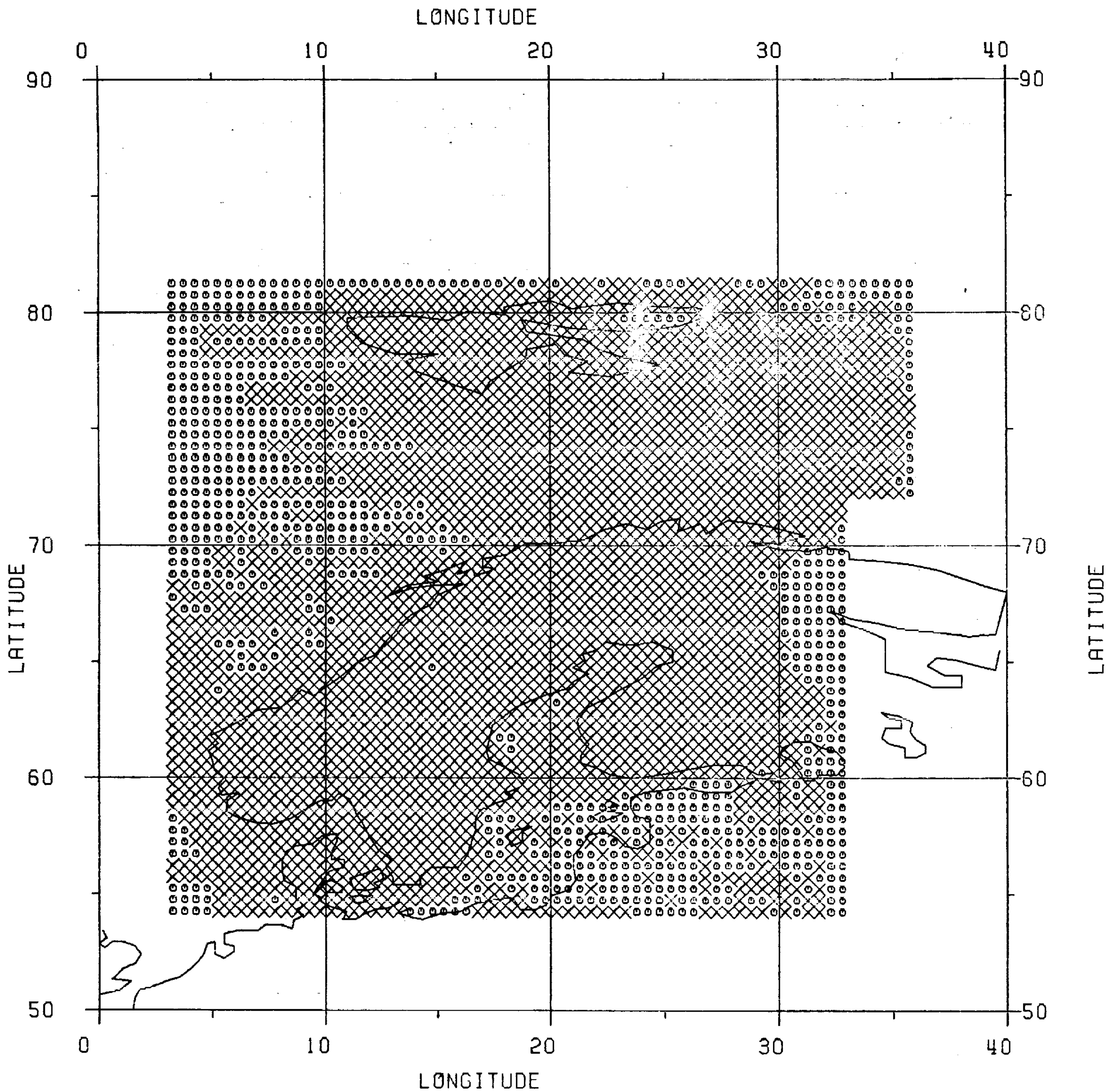

Figure 11. Location of 3414 30′ Mean Anomalies in Source 1022
(x = observed (2601); 0 = interpolated (813))

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3.16 Source 1026

This source is based on point free-air anomalies in Antarctica. The data was purchased from the National Geophysical Data Center in Boulder. It was sent on 9/14/88 on tape W02761. The NGDC product number is 896-A07-003 (Gravity Data Base, SE-0701, 6/88, National Geophysical Data Center). One file of data was compiled by the Defense Mapping Agency Aerospace Center in 1984. The second file of data was compiled in 1985 by the Soviet Union.

File 1 contains 57150 Russian values and file 2 contains 57140 DMAAC values. After questionable values were eliminated, the remaining values were thinned by 2′ blocks into choosing values in the most north-east part of the block. The thinned values were separately averaged to form two 30′ mean value files, TS0040.ANTRCTC.ANOM.MIN30X30.GRS67 (from file 1), and TS0040.ANTRCTC.DMA.ANOM.MIN30 (from file 2). A discussion on the accuracy estimation is presented in a later section.

The distribution of the thinned DMAAC data is shown in Figure 12-A. The distribution of the 30′ mean values is shown in Figure 12-B.

3.17 Source 1027

This source is 57 30′ free-air anomalies in South Korea brought to The Ohio State University by Choi in 1989. The 1666 point gravity values were given on a floppy disk and 30′ mean free-air anomalies were in a tabulated map. Additional information (May 89) showed that the 30′ mean Bouguer anomalies were calculated from the point Bouguer values and they were converted to 30′ mean free-air anomalies (Δg_f) by the following formula:

$$\Delta g_f = \Delta g_B + 2\pi G \rho H \tag{8}$$

where

$\rho = 2.67$ g/cm^3 for $h \geq 0$

$\rho = 2.67 - 1.03$ g/cm^3 for $h < 0$

G is gravitational constant.

H is the 30′ mean elevation averaged from 1 km x 1 km mean elevations from the Korean Geophysical and Surveying Institution,

The anomaly accuracy was assigned through equation (1). The distribution of the gravity stations is shown in Figure 13 (Choi, 1986).

3.18 Source 1028

This source is from free-air and Bouguer anomaly maps in the Mid-Andes area prepared by Götze and sent by Becker in a letter dated 9/16/87.

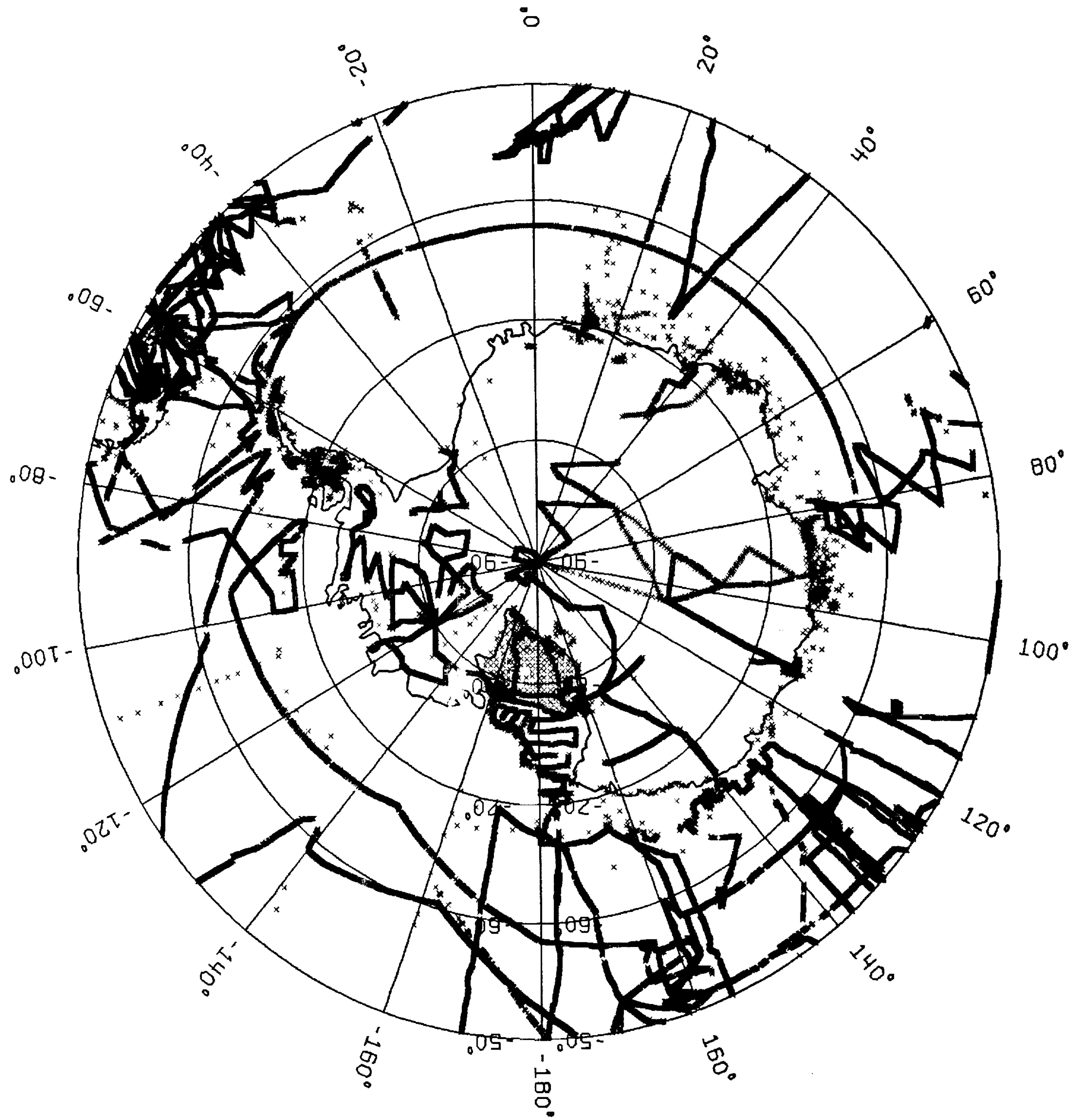


Figure 12-A. Distribution of 43792 2′ Thinned Point Values from DMAAC Data of Source 1026

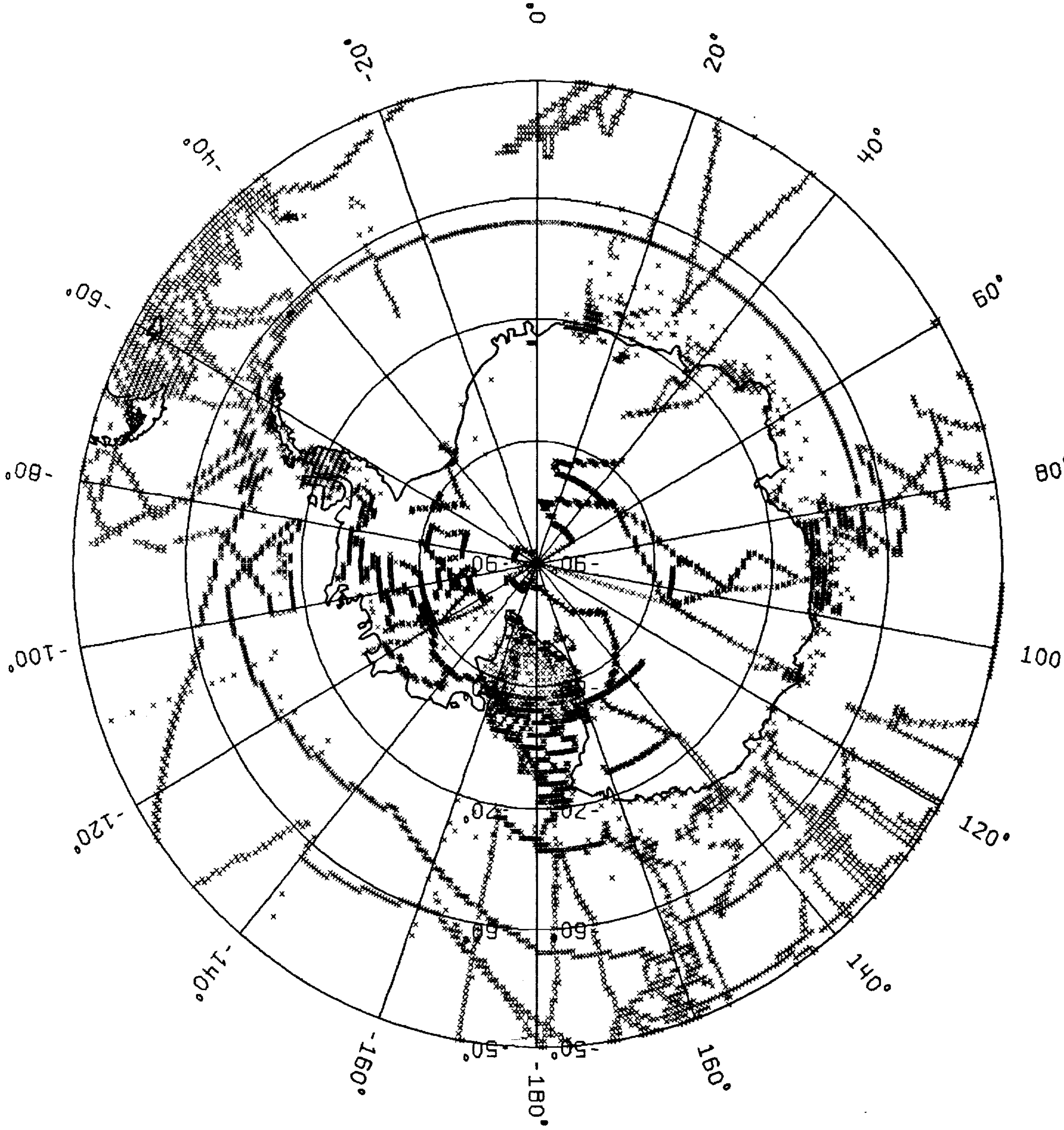


Figure 12-B. Location of 7154 30′ Mean Anomalies Computed from the DMAAC Data of Source 1026

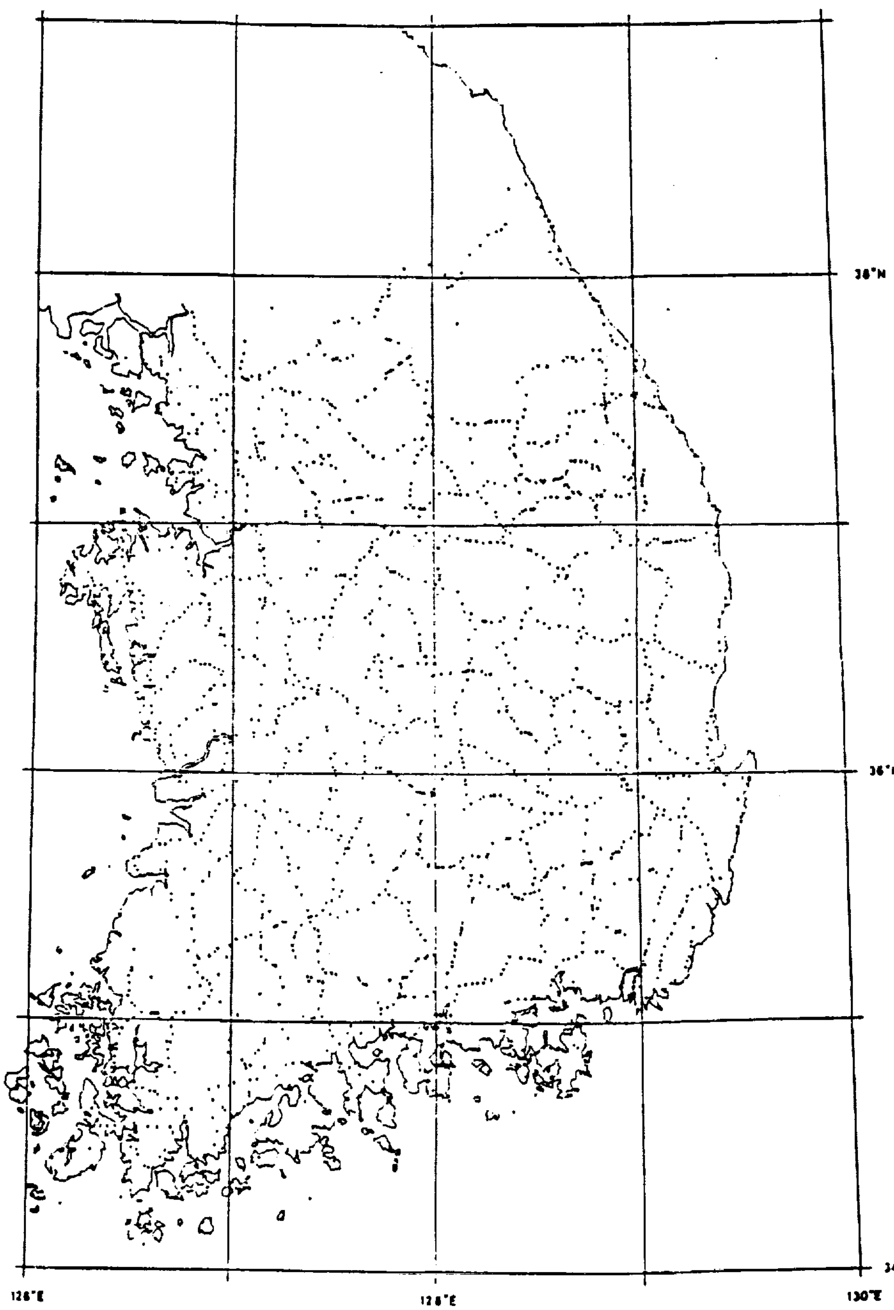


Figure 13. Distribution of Point Anomalies Used in the 30′ Mean Anomaly Estimation for Source 1027 as Provided by Choi

The free-air anomaly map was divided into 30′ blocks and each 30′ cell was divided into 4 cells, and mean values of these cells were visually estimated. The 30′mean values were then the simple average of these 4 cells with a total of 163 30′ mean values were estimated. Standard deviations were assigned as 10 ~ 30 mgal based on the complexity of anomaly contour lines. Because of the rugged elevation of the area and the lack of additional information these anomalies may be unreliably estimated.

3.20 Source 1029

This source contains 16796 30′ mean free-air anomalies in Africa area sent for Fairhead by Green on behalf of the African Gravity Project. The transmittal letter was dated 3/02/89, with the data on tape F37699.

The original point data available to the African Gravity Project was used to calculate an approximate 2.′5 grid. To do this, an average position and average value was determined. This data was then used in an interpolation procedure to construct values on a 5′ grid. The interpolation procedure was a minimum curvature procedure (Briggs, 1974, p. 39). This procedure was implemented using a variable distance selection criteria depending on data availability. These values were then averaged to form 30′ mean values which were sent to Ohio State. In addition to the 30′ mean anomaly, the number of data points within the 30′ cell were provided. In some cases this count was zero so the 30′ estimate was based on points outside the cell. We chose to delete such interpolated values from our final anomaly selection.

The gravity formula used is that of GRS67. The standard deviations were calculated by equation (1) with n equal to the number of points in the 30′ cell. The distribution of the 30′ values is shown in Figure 14.

3.21 Source 1030

This source contains 5′ x 5′ mean free-air anomalies in Japan and nearby seas sent by Segawa with a letter dated 3/20/89. The data is on tape JAPAN. The tape contains 2 files: the first file contains mean values on land, and the second file contains mean values in sea areas.

These 2 files were merged into one file and 5′ mean values were averaged to form 2367 30′ mean values. After various tests described in Source Analysis Section 4.6.3 we decided to apply a Bouguer correction for land data as follows:

$$\Delta g_{COR} = \Delta g + 0.1119 * (H_1 - H_2) \text{ (mgals/m)} \tag{9}$$

where: Δg_{COR} is corrected 30′ mean free-air anomaly

Δg is the original 30′ mean free-air anomaly

H_1 is the 30′ mean elevation from the OSU JAN 89 (TUG87) file

H_2 is a 30′ mean elevation based on the 5′ data given on the tape JAPAN

This correction was to take into account the elevation difference implied by the point elevations and the more representative mean value from the OSU 30′ elevation file.

Later on, responding to a request by Rapp, on 3 questionable 30′ blocks, revised 5′ mean values in those 30′ blocks were received (letter dated 4/26/89 by Segawa).

The standard deviations were estimated by equation (1) with n equal to the number of 5′ mean values within the 30′ block. The locations of the 5′ mean values on land and sea are shown in Figure 15-A and 15-B respectively.

3.22 Source 1031

This source is from the Bouguer anomaly map of Sri Lanka in The National Atlas of Sri Lanka by the Survey Department of Sri Lanka (Somasekaram, 1988). Visual map estimation of 30′ Bouguer anomalies was made by dividing a 30′ block into 4 smaller blocks. Then the mean Bouguer anomalies were transformed to mean free-air anomalies by following equation (8) where H is from the TUG87 30′ mean elevation file. Accuracies are assigned to be 5 to 20 mgal based on the complexity of anomaly contour lines.

3.23 Source 1032

This source is 30′ mean free-air anomalies in the Eastern Mediterranean ($31° \leq \phi \leq 37°$; $26° \leq \lambda \leq 36°$) sent by Arabelos in a letter dated 5/10/89, in the tape designated XYT433. The tape contains two files: file 1 with 6′ x 10′ mean free-air anomalies and file 2 with 30′ anomalies. The accuracy of the point values is ± 5 to ± 10 mgal. Arabelos points out that the distribution of the point data makes the estimation of the accuracy of the 30′ mean values difficult. We have assigned an accuracy of ± 10 mgal to each 30′ mean in this source.

The 30′ values were computed as the simple mean of the corresponding 6′ x 10′ mean free-air anomalies covering the 30′ x 30′ area. The data sources used in the 6′ x 10′ evaluation are described by Arabelos (1980). A terrestrial data coverage map may be found in Arabelos and Tscherning (1988).

3.24 Source 1033

This source is based on point Bouguer and free-air anomalies in Central America received in May 1989. This data set is stored on file 1 of tape AIKGR1 sent by Aiken with a letter dated 05/11/89. This data set was originally processed by Tsaoussi at Ohio State who checked the data for duplicate data points, anomaly inconsistencies, etc. The modified point data set consisted of 6740 values. A 2′ x 2′ thinned data file containing 2867 points (Figure 16) was created. The thinned data set was created by selecting a single point nearest the center of the 2′ x 2′ cell. The 98 30′ mean anomalies were formed from the 2′ x 2′ values. If the average 30′ elevation H (TUG87, tape GS367) was greater than 100 m the mean free-air anomaly was computed using equation (2). If the elevation was less than 100 m the 30′ average was taken as the average of the free-air point values. The standard deviation of the anomalies was computed from equation (1) with n equal to the number of thinned values. The data set was stored as TS3177.CENTRAL.AMERICA. MEANANOM.

3.25 Source 1034

This source is a set of point values in the Texas area from file 2 of tape AIKGR1. The data analysis was carried out as described for Source 1033. There were 82582 values in the selected file that were reduced to 51414 in the thinned file. The distribution of the thinned (2′ cells) anomaly set is shown in Figure 17. A total of 645 30′ anomalies were estimated. They were stored on data set TS3177.TEXAS.MEANANOM

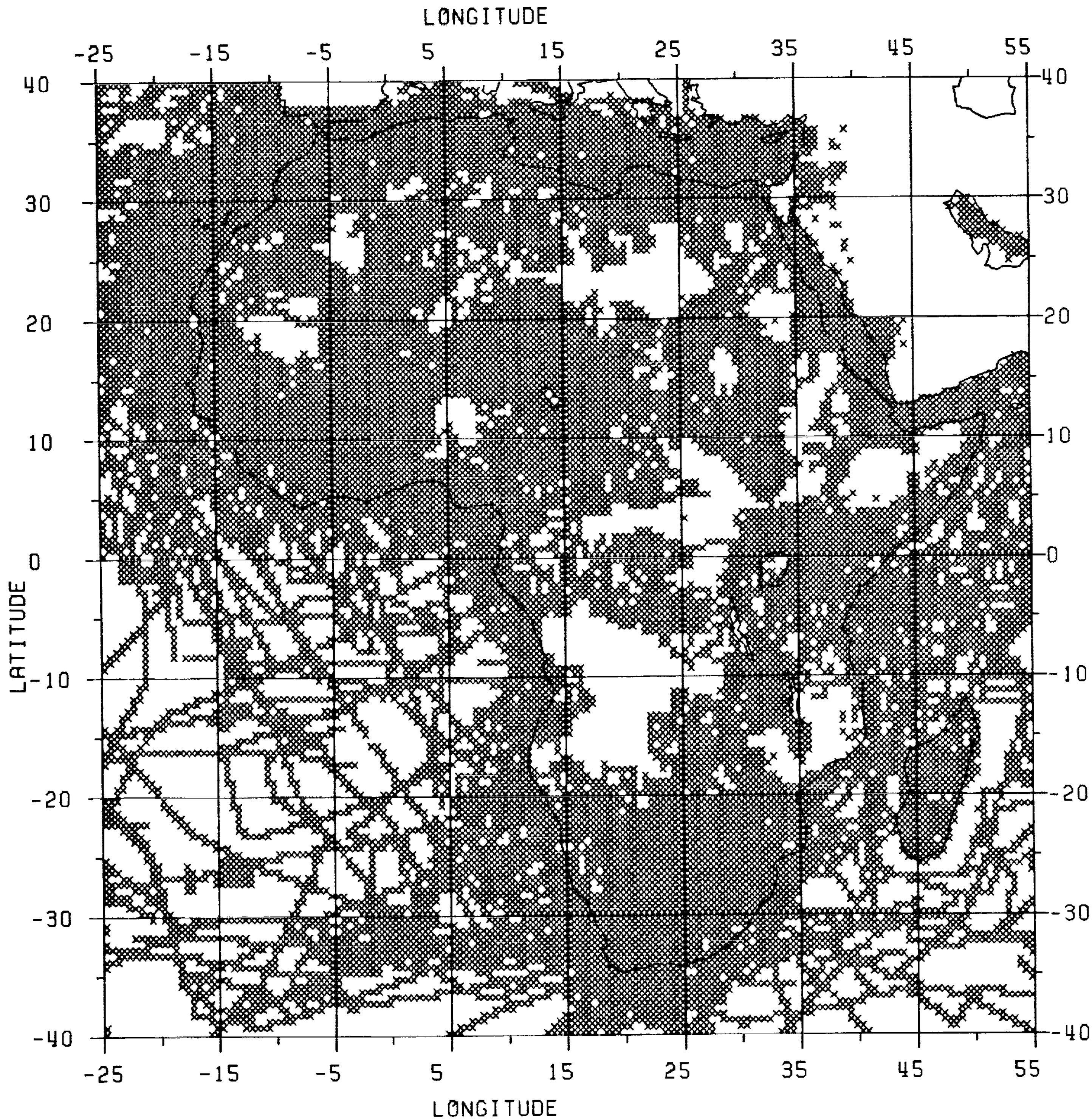


Figure 14. Location of 16796 30′ Mean Anomalies of Source 1029

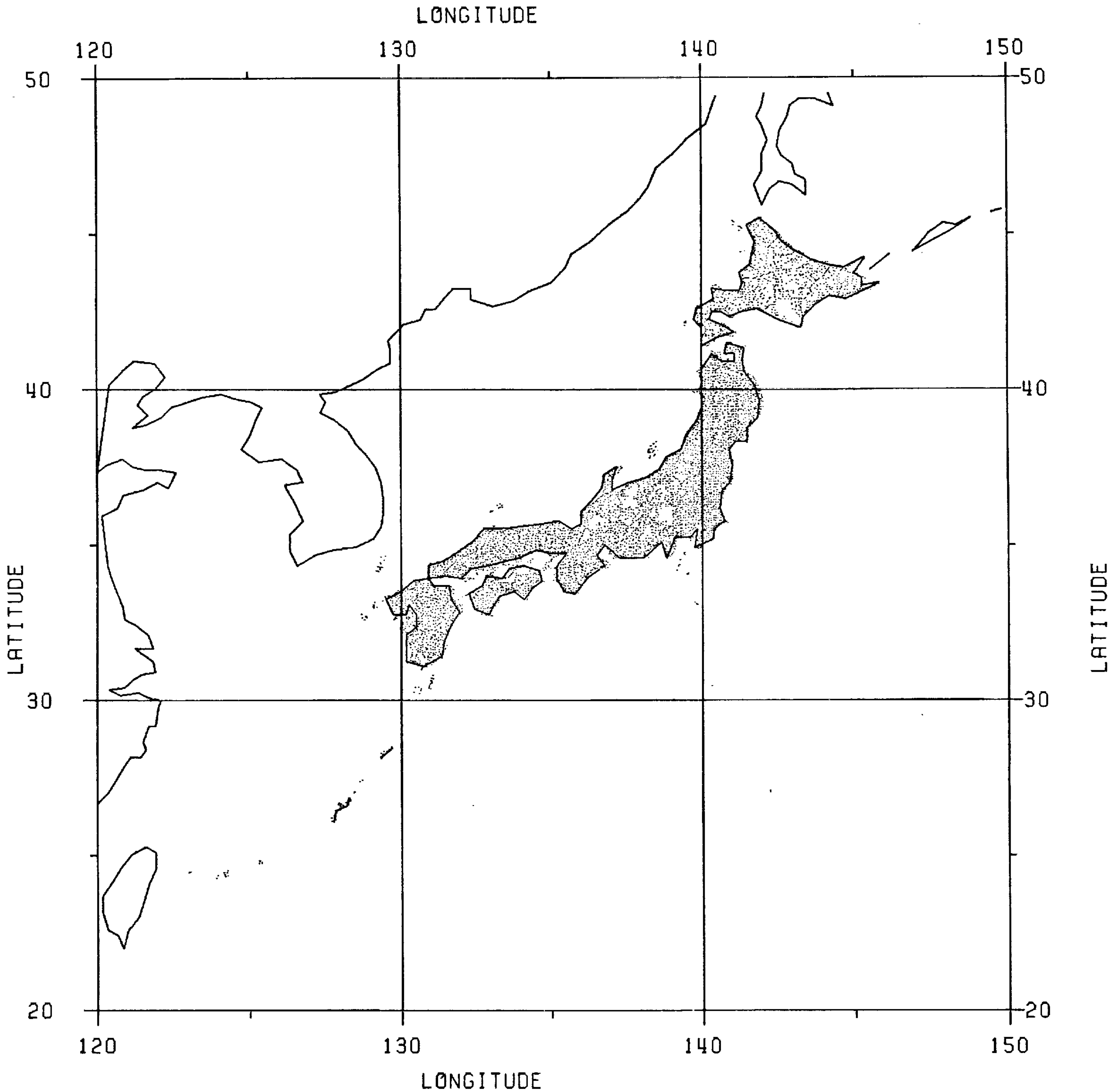


Figure 15-A. Location of 5040 Land 5′ Mean Anomalies of Source 1030

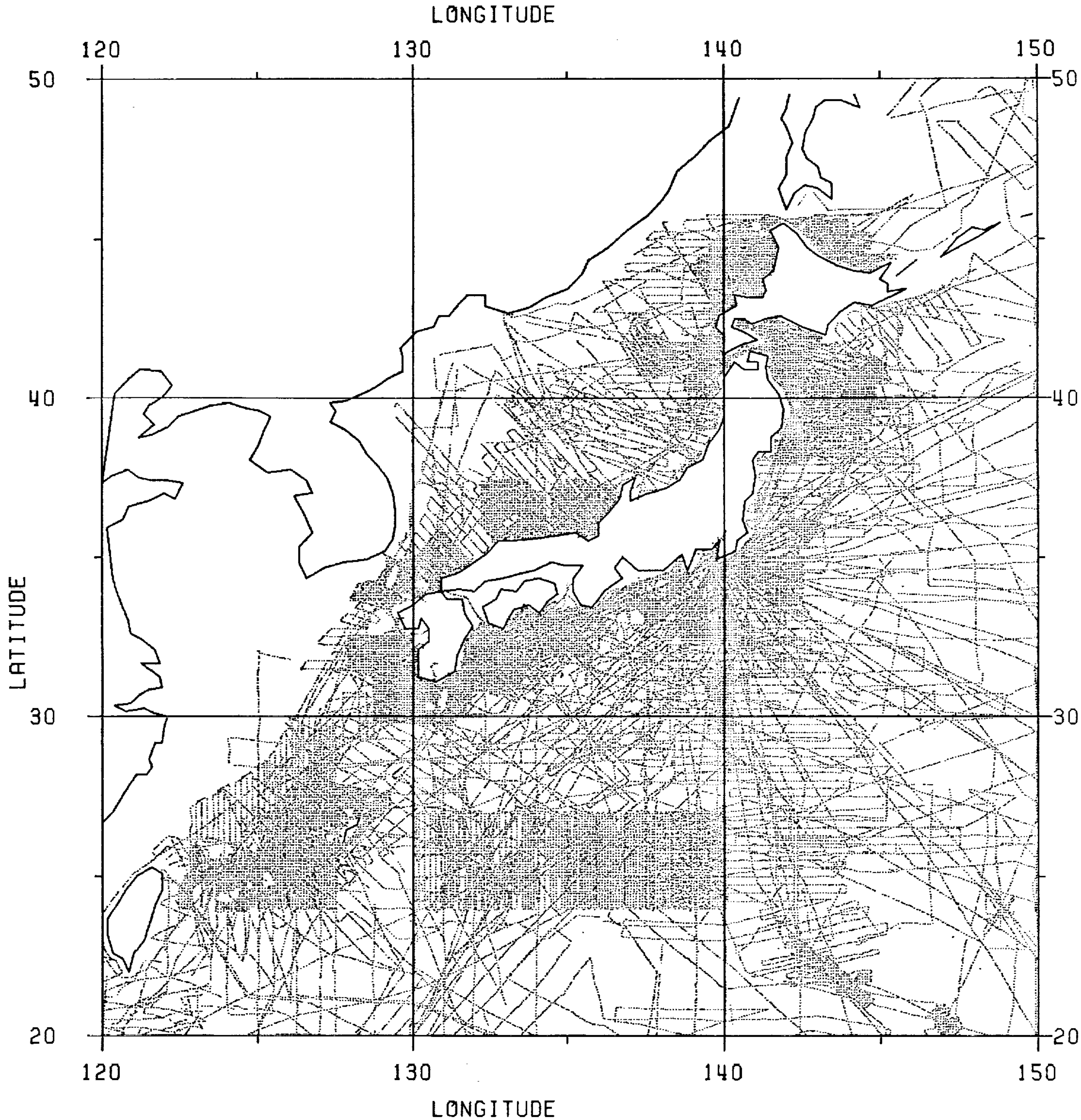


Figure 15-B. Location of 2367 Ocean 5′ Mean Anomalies of Source 1030

3.26 Source 1035

This source contains 195 30′ mean free-air anomalies in England sent (via BITNET) by Gerrard, on 6/16/89, and 6/23/89. The former set has its reference coordinate as the center of the 30′ cell so that it cannot be used in our system which has its reference coordinate at the northwest corner of the cell. The latter set is referenced to the north west corner. The standard deviations were estimated by equation (1) using the number of given data points. The location of the 30′ values in this source are shown in Figure 18.

3.27 Source 1036

This source consists of 5 km x 5 km gridded point free-air anomalies in Canada and the northern part of USA from the tape GDS126 sent by Hearty, Geological Survey of Canada, Ottawa, Ontario, in a letter dated 2/18/88. The gridded point values were averaged to form 12865 30′ mean values and standard deviations estimated by equation (1). The distribution of the 30′ anomalies computed from tape GDC126 are shown in Figure 19.

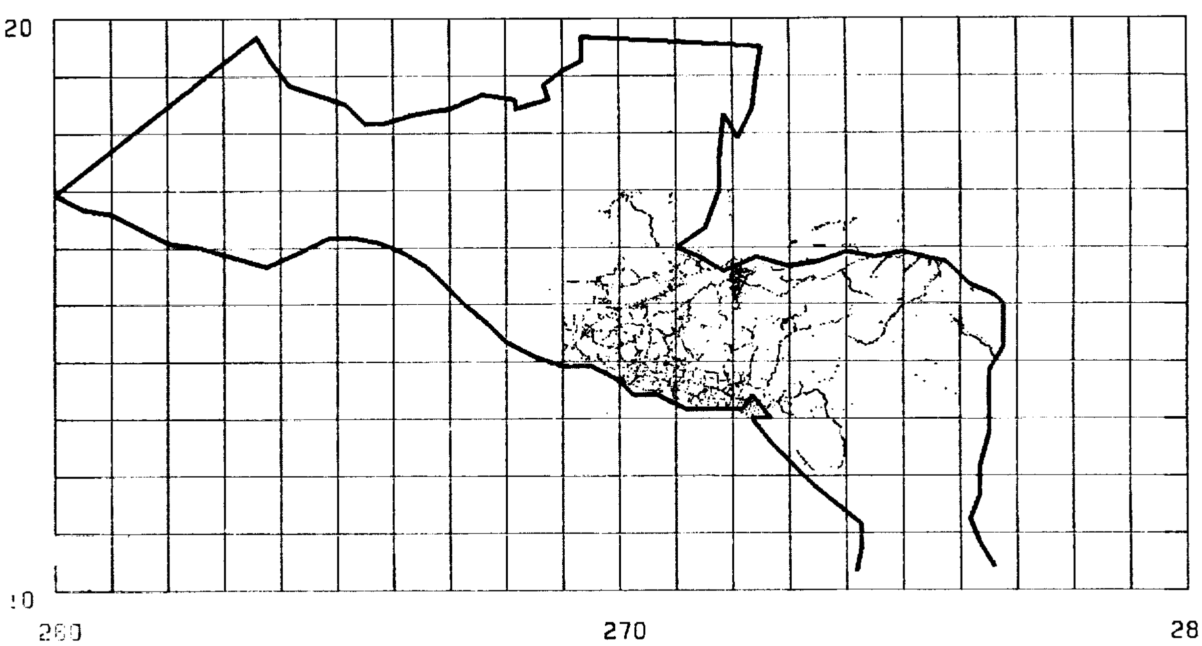


Figure 16. Location of 2867 Thinned Point Values from Source 1033.

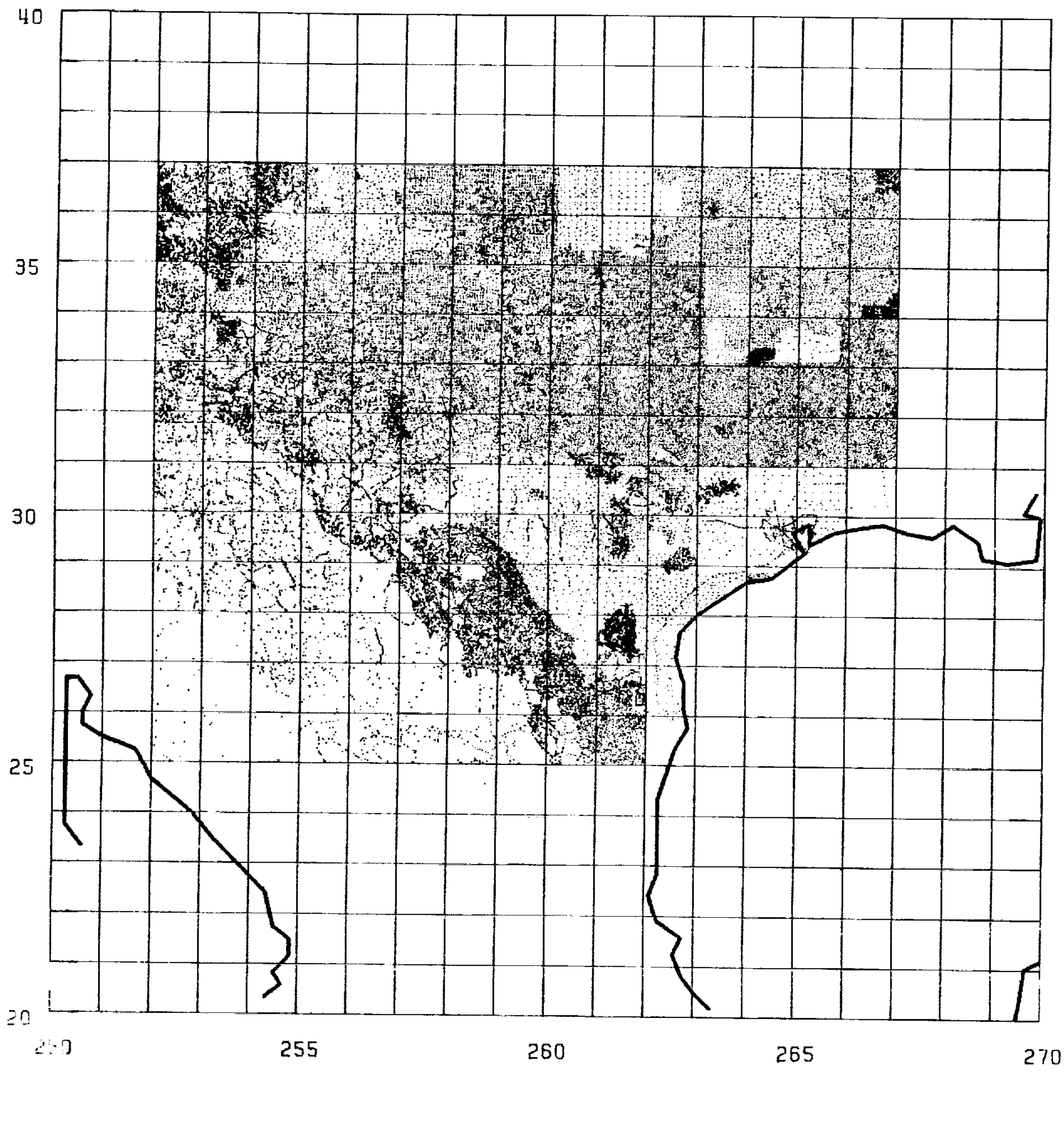


Figure 17. Location of 51414 Thinned Point Values from Source 1034

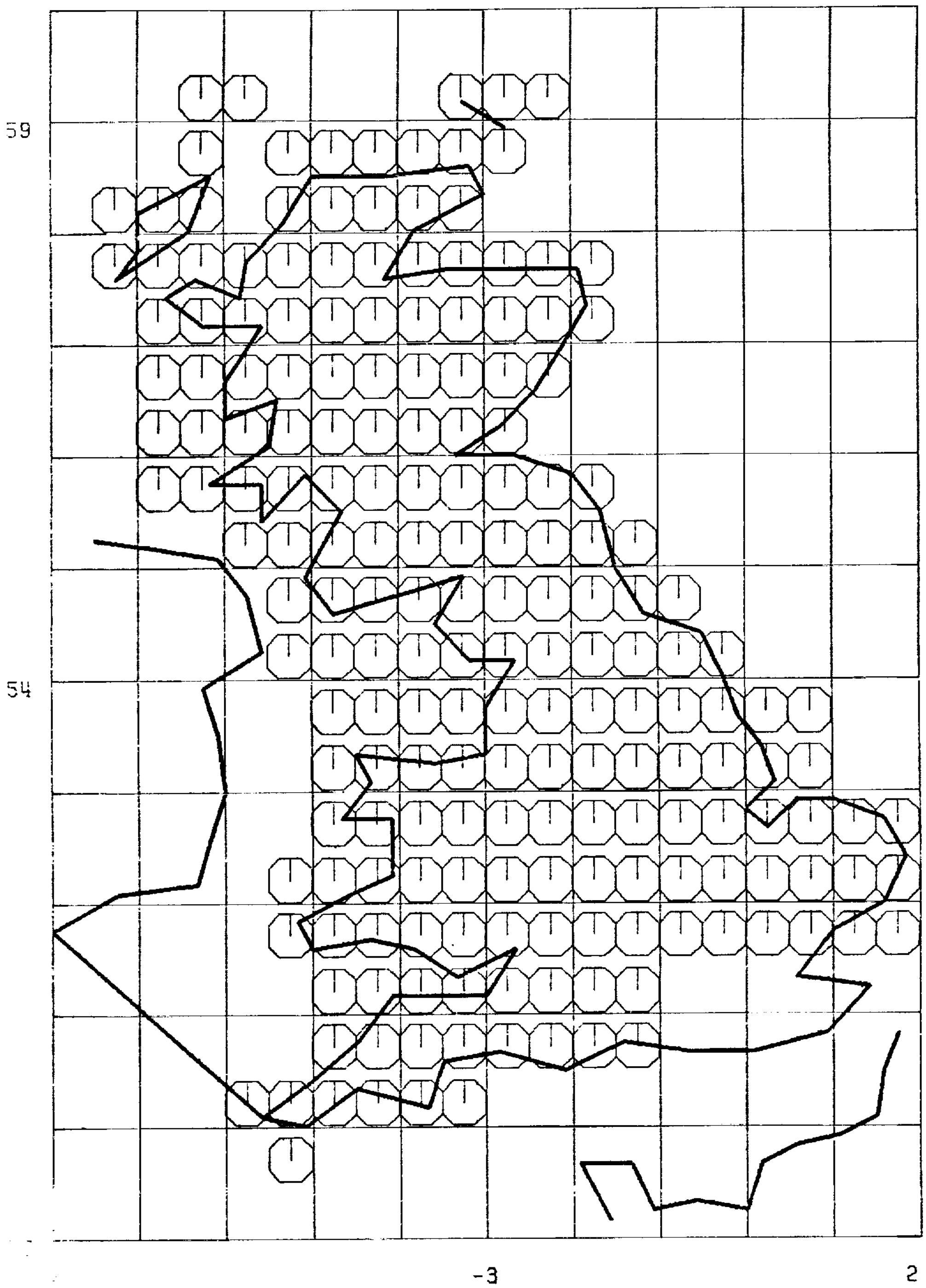


Figure 18. Location of 195 30′ Mean Anomalies in Source 1035

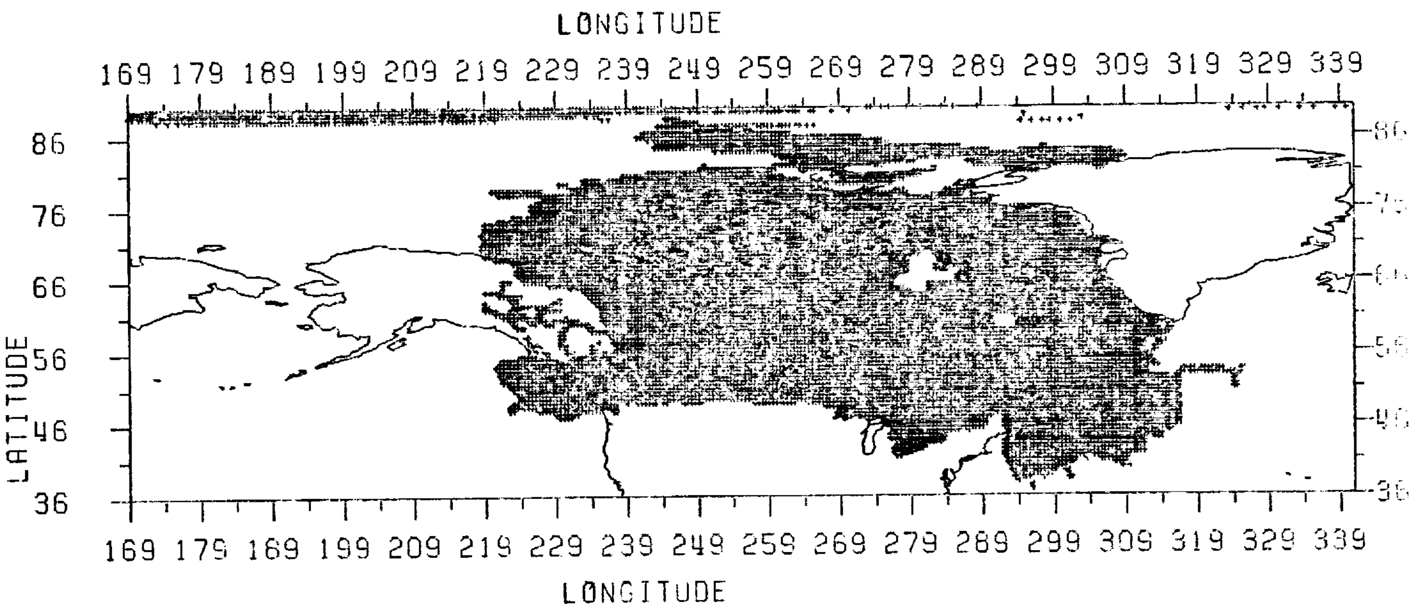


Figure 19. Location of 12865 30′ Mean Anomalies in Source 1036 as Computed from Data on Tape GDS 126.

3.28 Source 1037

This source comes from file 3 of tape AIKGR1 received in May 1989 from Aiken. The data in this file is primarily in the Mexico area and includes data provided by Maurico F. de la Fuente. The data was checked and processed by Tsaoussi in a manner similar to that used for Sources 1033 and 1034. There were 150660 values in the selected file which were reduced to the 66640 values in the thinned file. The 1158 30′ mean values were computed from the thinned data and stored as TS3177.MEXICO.MEANANOM. The distribution of the thinned set of anomalies is shown in Figure 20.

3.29 Source 1038

This source comes from file 4 of tape AIKGR1 from Aiken. The data in this file covers portions of South America. The processing of the point data was carried out using the techniques implemented for Source 1033. There were 139238 values in the selected file and 90051 in the thinned file. A set of 6064 30′ mean anomalies was computed from the thinned data set. The distribution of the thinned set of anomalies is shown in Figure 21. The 30′ mean anomalies were stored as TS3177.SOUTH.AMERICA.MEANANOM.

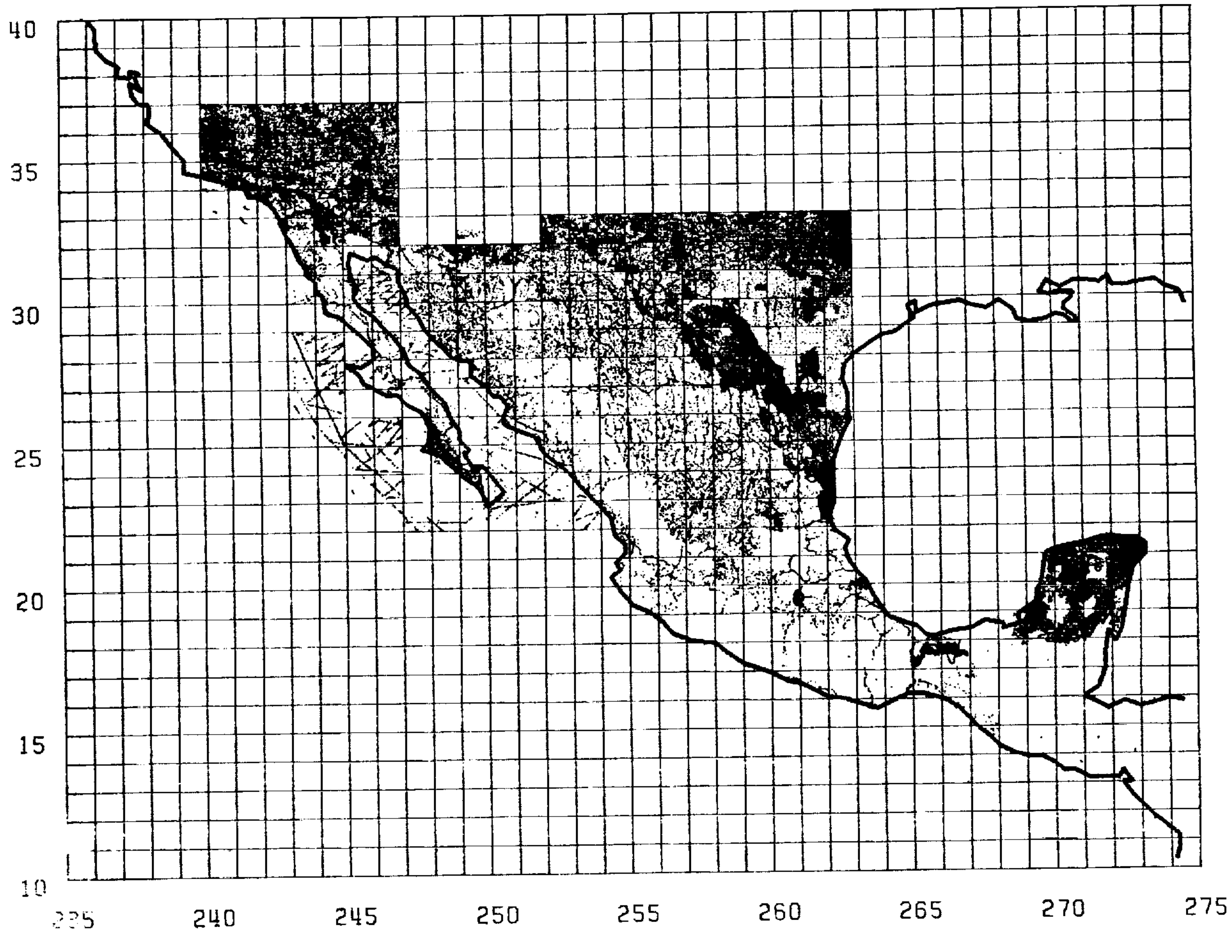


Figure 20. Location of 66640 Thinned Point Anomalies from Source 1037

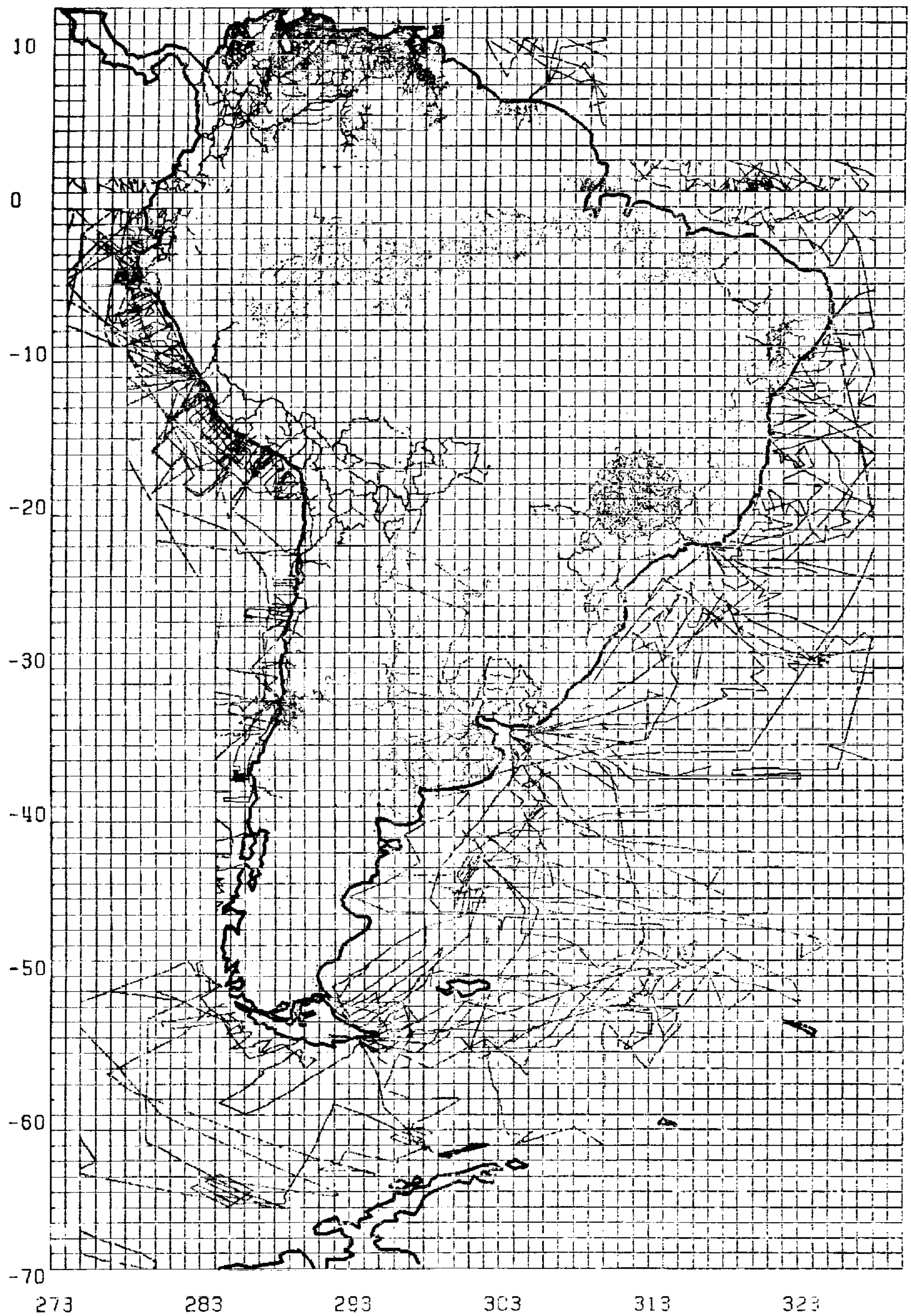


Figure 21. Location of 90051 Thinned Point Anomalies from Source 1038

4. Source Analysis and Anomaly Selection

The sources discussed in the previous section now have to be merged with the August 1986 30′ file. This will be done through a series of updates the first of which creates file 11 on tape GS327. Update 2 will create file 12, etc. In carrying out these updates decisions must be made on the anomaly to use when more than one anomaly estimate exists for a cell. This section will discuss how these decisions have been made.

It will be more convenient to carry out these discussions by geographic regions where at least 3 sources (including the August 1986 estimate) are available. There are seven regions for discussion, each depending on the availability of data, and the sequence of the update. For the first six regions, the updates could be done more than once when 3 sources exist. The last region had only two sources of information so that only one update was carried out.

In this discussion several references will be made to program F292K. This program takes an existing master file and carries out a comparison and preliminary data selection using a new data file.

4.1 Sources for North America and Greenland

4.1.1 Source S11, S1011, and S1036

The primary gravity field information from this area in the August 1986 field was from S1002. Numerous new sources are now available for this region. The major new data was contained in S1011 and S1036. Originally these two sources were not identified as separate sources. Instead the data of these sources was merged to form Source 11 (S11), a designation later dropped, as will be discussed.

The Canadian data contained 12865 30′ anomalies (called S11B) while the U.S. data contained 4973 30′ anomalies (called S11A). These values contained 417 duplicate values. S11 was formed by merging S11A and S11B using the following criteria applicable to the duplicate cells:

Accept S11A if the number of gridded points is ≥ 47, and the number of points of S11B is less than 32; otherwise take S11B if the number of points in S11A is less than 47 and the number of points in S11B is ≥ 32. The number of points (47,32) corresponds to approximately a 25% areal coverage of the 30′ cell for S11A and S11B respectively.

Source S11 was considered an improved data set from S1002 (or S2) of the August 1986 file based on comparisons with other data sources not specially used in our update. This included comparisons with data of the Bureau Gravimetrique International (1988), and information given in Watts et al. (1985).

S11 was included as one of the sources in update 1. In making this update with program F292K, S11 was preferred over S1002 in land areas. In ocean areas the source that agreed best with reliable (standard deviation ≤ 10 mgal) altimeter derived gravity anomalies was selected. In addition S11 was chosen to replace S1007 which covers a portion of eastern Greenland.

After an update was completed with S11 it was discovered (through the suggestion of R. Fury) that there were some problems with data in S11A. To consider this a comparison was made between S11A and the August 1986 data. A run (TS475776) was made on 5/23/89 to identify blocks with significant discrepancies. For some blocks, point anomaly plots were made using point data from S11A (later to be called S1011) and S1021. This revealed that some gridded values in S11A were of very questionable value. Another test was made comparing S11A and S11B in overlap areas. Large discrepancies were found along the Canadian border.

Additional tests were carried out by creating 30′ x 30′ mean values from a point anomaly data tape (GS202) from the National Geodetic Survey. These tests (e.g. TS475741 on 6/13/89) revealed a serious problem with some of the data in S11A. To reduce this problem it was decided to basically accept S11B derived 30′ anomalies in the U.S. area and split S11 into two sources (S1011 and S1036) which would contain our best judgment anomaly estimates. To do this a subset of S11B was created where $\phi \leq 49.5°$ (TS4757.MCANFAM.BORDER). This file was compared to update 1 (with S11) using F292K. In doing this a "human choice" was made to accept a S11B value if the number of data points was > 45; a S11A value was retained if S11B points were ≤ 45. The output from this file was merged with S11B values with $\phi \leq 50^{\circ}\!.0$ to form S1036. This source was then used to replace all S11 values on the earlier update. In addition the S11 values not replaced by S1036 were designated S1011. As a result, S1036 contained values only from S11B, and S1011 contained values only from S11A.

4.1.2 Source 1019

This source had 227 common blocks with S1002. An F292K run showed that most (187) of the overlaps occur in sea areas. The S1019 values were found to be reasonably consistent with S1002 values and altimeter derived anomalies. On land areas, S1019 was found to be more consistent with other data so that values from S1019 were accepted over S1002 values on both sea and land. In the update procedure 14 values were found to overlap with S11. As S11 had better coverage for most of the overlapped blocks, S11 was accepted over S1009.

4.1.3 Source 1021

There were 12637 30′ anomalies in this source with 11990 values in common with S11 (S1011). The mean difference (S1021-S11) was -0.23 mgal with a root mean square difference of ± 8.3 mgal. This indicates a good agreement between these two data sets. Consequently we decided to accept only the new (647 values) from S1021.

S1021 had 49 duplicate values with the August 1986 field. 48 of the 49 values were common with S1002. Various comparisons with other sources led us to accept S1021 over S1002. The remaining duplicate value was retained in the original source (S1007) as S1021 had only one point value in the cell.

4.1.4 Source 1020

This source had no common values with other new sources but had 10 common values with S1002. For those 10 values, 8 agreed excellently (RMS difference = 3.8 mgal) and 2 had poor agreement. For these two values, S1020 was more consistent with the altimeter (1985) anomalies. Furthermore, this source is regarded as more reliable as hundreds of point values are used to calculate a 30′ mean value. We decided to accept S1020 over S1002.

4.2 Sources for Texas and Central America

For this region S1002 was available from the August 1986 field. New data sources were S1011 (update 1), S1033 and S1034 (update 4), and S1037 (update 5) which were sequentially introduced in the update procedure. As discussed in the previous section, S1011 was chosen over S1002. S1037 also had common values with S1033.

4.2.1 S1034

We first ran F292K for S1034 against the file 12 of GS327 which had S1002 and S1011 for this region. For the common blocks, S1034 had excellent agreement with the data on file 12 but some values of S1034 had large discrepancies with S1002 or S1011. It was interesting to see some S1034 values that had large discrepancies with S1011, were in good agreement with S1002 values. This may be because S1011 had some bad values in this area (as was found to be the case near the Canadian border). Further comparison of 1° averages of S1002, S1011, S1034 and DMAAC values (1989) confirmed this, i.e., S1034 implied 1° values agreed better with DMAAC '89 values than S1011. Also this comparison showed S1034 agreed better with DMAAC '89 than S1002. The final human choice is that S1034 is accepted over S1002 and S1011.

4.2.2 S1037 and S1033

S1037 had common values with S1002, S1011, S1033 and S1034. Careful review of a F292K run against the file 14 of GS327 containing S1002, S1011, S1033 and S1034, and comparison of 1° averages of S1002, S1011, S1037 and DMAAC '89 showed the following:

A. S1037 is in excellent agreement with S1034;
B. S1011 agrees better with DMAAC '89 than S1034 does except 6 30′ blocks of S1011 which may be the bad values of S1011 as discussed above.

Considering that S1037 has a quality similar to S1034 as shown in item A and that S1034 was chosen over S1002, the following human choice was made: accept S1037 over S1002 and retain S1011 over S1037 except for 6 values which were more reliably determined in S1037. Meanwhile, there were 9 common block between S1037 and S1033. For those blocks, S1033 had better coverage and it was retained as the anomaly standard deviations were smaller.

Figure 22 shows the locations of large discrepancies between S1037 and file 14 of GS327 (containing S1002, S1011, S1033, S1034).

4.3 Sources for South America

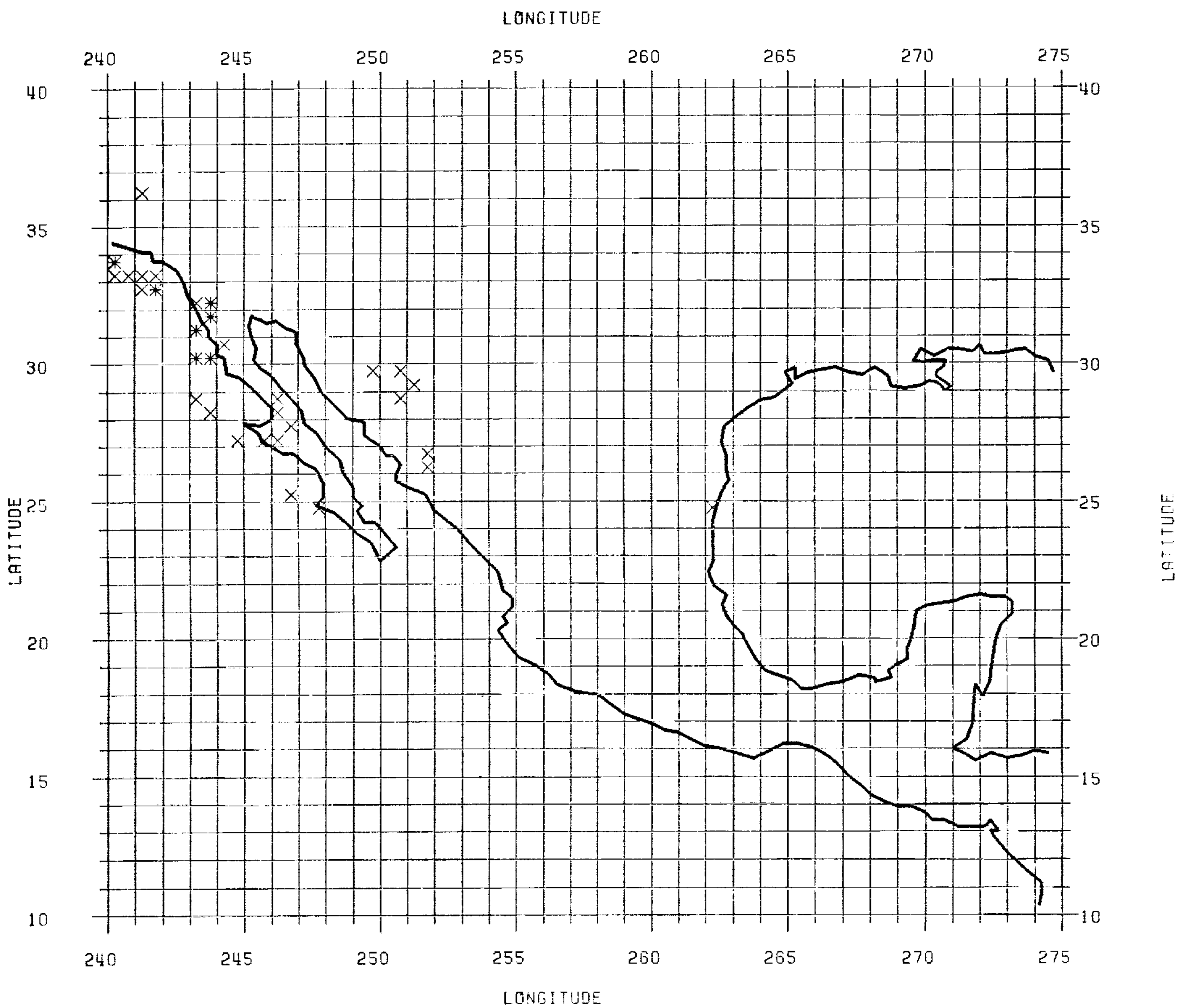
For this region S1005 was available from the August 1986 field. S1013 was introduced at update 1; S1026 and S1028 were introduced at update 3. S1026 and S1028 had no common blocks with each other. S1038 was introduced at update 5. S1038 had overlaps with S1005, S1013, S1026 and S1028.

4.3.1 Source 1013

This source has an excellent agreement with S1005 (RMS difference is ± 5 mgal). Except for one anomaly at $\phi = 23°$, $\lambda = 316°$ near the coast, which was deleted, we let F292K choose the proper values according to the standard selection criteria.

4.3.2 Source 1026

This source had no common block with the previous 30′ terrestrial data when introduced. The F292K run gave comparison of this source with the 1989 altimeter anomalies data (Hwang, 1989) for 2763 values out of 7154. Further comparisons of 1° averages from this source with the 1989 altimeter anomalies, BGI, Watts et al (1985) and the June 1986 update were made. The 30′ values from Russian data (file 1) were so inconsistent with most of other values that we decided not to use them.



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OF POOR QUALITY

Figure 22. Location of 30′ Mean Anomalies Having Discrepancies Greater Than 80 mgals (*) Between S1037 and Sources on File 14 of GS327. Discrepencies Between 40-80 mgal are designated with an x.

The 30′ anomalies from the DMAAC point data (file 2) had reasonable agreement with other data. Figure 23 shows the location of blocks of $\phi \leq -63^\circ.5$ with more than 60 mgal discrepancies between S1026 and altimeter anomalies. An ocean floor map showed those blocks are mostly on trenches, ridges or near islands where the altimeter data may not be reliable.

Since we had no other terrestrial data to be compared for this region except altimeter data, the accuracy estimation was carefully reviewed for the future updates. The average standard deviation of the altimeter (1989) anomalies is about 6 mgal and the RMS difference between S1026 and the altimeter anomalies was about 19 mgal. Therefore, we can estimate the standard deviation of S1026 by the following formula:

$$\sigma_{alt}^2 + \sigma_{S1026}^2 = 19^2 \quad \text{(mgal)}$$

$$\sigma_{S1026} = 18 \quad \text{(mgal)}$$

Considering the RMS 30′ mean value of S1026 was ± 25 mgal and the number of points in a 30′ cell for the thinned blocks of $\phi \leq -63^\circ.5$ was 10, equation (1) can be written as:

$$18 = \frac{X}{\sqrt{10}} + 0.05 * |25| + 0.5 \quad \text{(mgal)}$$

Solving for X we have X = 52 mgals. The modified equation (1) is then:

$$\sigma = \frac{52}{\sqrt{N}} + 0.05 * |\Delta g| + 0.5 \tag{10}$$

Equation (10) was used for accuracy calculations for this source.

4.3.3 Source 1028

This source had no common values with the previous field. Comparisons of 1° averages implied by this source with those from the altimeter anomalies, Watts et al. (1985), BGI, and the June 1986 1° field showed moderate agreement with all sources except the June 86 where the comparisons were poor.

4.3.4 Source 1038

This source had good agreement with S1005 and S1013 (RMS difference of 7 mgal and 5 mgal respectively). It also had generally reasonable agreement with S1026 though some blocks had 100 mgal discrepancies. Figure 24 shows locations of blocks with large discrepancies (≥ 40 mgal) between S1038 and sources on file 14 of GS327.

A comparison of this source with those of S1026, S1028 and the 1° DMAAC '89 values led us to the following conclusion: accept S1038 over S1028; otherwise let F292K choose the proper values using the standard criteria.

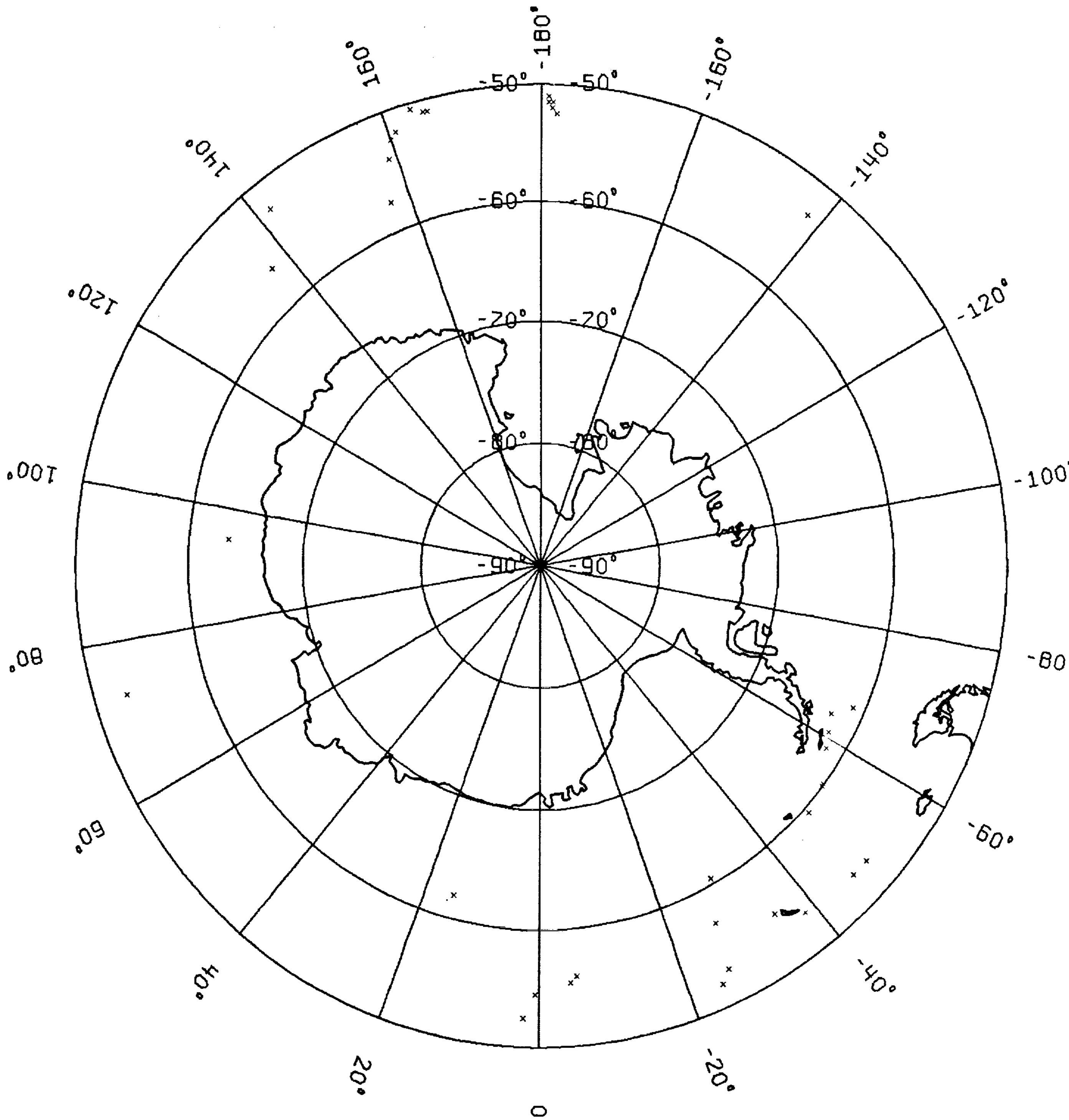

Figure 23. Location of 30′ Blocks, Below $\phi = -63\overset{\circ}{.}5$, Where Anomaly Discrepancies (S1026 vs Altimeter Anomalies (1989)) Exceed 60 mgal

4.4 Sources for Europe

For this region, S1004 was available from the August 1986 field. S1014 was introduced at update 1; S1022 and S1025 were added at update 2, and S1035 was added at update 5. None of these 4 new sources had any overlap with each other. S1032 covers the Eastern Mediterranean and the northern part of S1029 covers most of the Mediterranean. There were overlaps with S1004 and S1014. Analysis of these 2 sources will be discussed in the next section.

4.4.1 Source 1014

Recalling that S1004 and its accuracies were calculated from 6′ x 10′ block mean values by least squares collocation (Despotakis, 1986) and the anomalies of S1014 were calculated from newer and smaller mean values of 5′ x 6.′25 blocks, we decided to accept S1014 over S1004. However, some blocks in the western (λ=19°) border have too few 5′ x 6.′25 mean values to be accepted over S1004 so that they were deleted (9 30′ values with $\lambda = 19.^\circ 0$), i.e., S1004 values were retained for these blocks. A block (at $\phi = 37.^\circ 5$, $\lambda = 28.^\circ 0$) was found to have a large discrepancy (110 mgal) so that the value of this block is also deleted because supportative data was lacking.

4.4.2 Source 1022

This source was in excellent agreement with S1004 (RMS difference was 8 mgal) and altimeter derived (1989) anomalies (RMS difference was 9 mgal). It was believed that S1022 contained the latest data in Scandinavian. Therefore we decided to accept this source over S1004.

4.4.3 S1025

This source had 3 blocks overlapping with S1004 and their 30′ values were in excellent agreement (RMS difference is 6 mgal). The 54 30′ values were then considered to be reasonable and accepted over other sources.

4.4.4 S1035

Comparison of 1° anomalies (from averaging 30′ values) from S1035 and S1004 with 1° DMAAC '89 values showed that values with better accuracies in either S1035 or S1004 agreed better with DMAAC '89 values. Since altimeter derived anomalies were found to be very inconsistent with both S1035 and S1004 in shallow sea areas, the altimeter anomalies were not used in the F292K as a criterion for source selection.

4.5 Sources for Africa and the Mediterranean Area

For the continent of Africa, S1001 was available and for the Mediterranean area, S1004 was available from the August 1986 field. S1014, S1015 and S1016 were introduced at update 1; S1024 at the update 2; S1029 at update 3 and S1032 at update 4. S1015 and S1016 had common values with S1001 and S1024 had common values with S1016. S1014 had overlaps with S1004 and S1032 had overlaps with S1004 and S1014. S1029 had common values with all other new and old sources for this region.

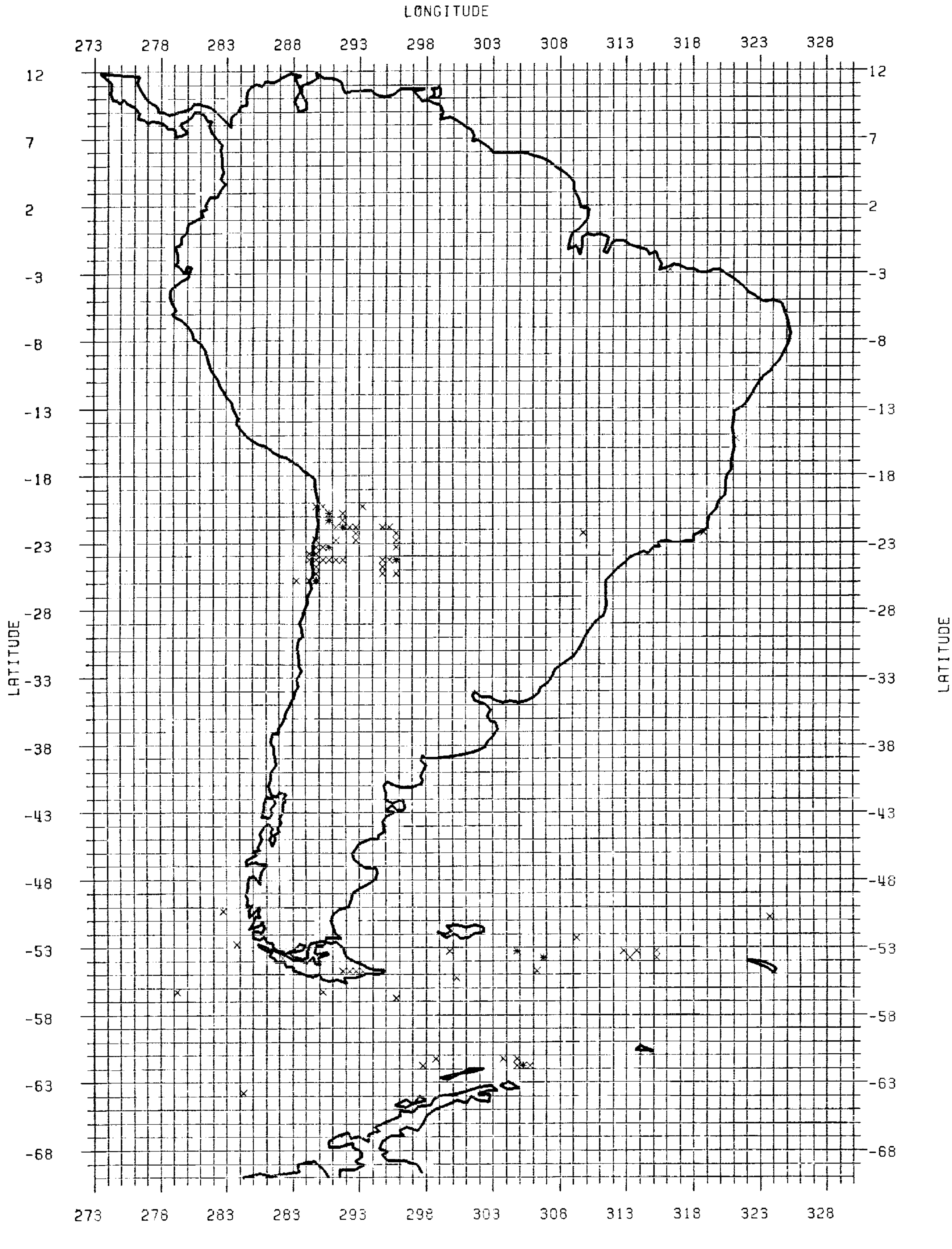

Figure 24. Location of Anomaly Discrepancies Between Source 1038 and File 14 of GS 327

4.5.1 Source 1015

The reference gravity formula and standardization network were not known for this source. As S1001 and S1016 had complete overlap with this source, we decided not to use the source.

4.5.2 Source 1016

We received S1016 mainly for Madagascar. It also contained values in continental Africa having overlaps with S1001. Old source S1001 had a better overall accuracy (±5.0 mgal) than the values in Source 1016 (±13.5 mgal). S1001 was formed by a least squares collocation procedure which was regarded as a better method than the simple averaging that was used for S1016. Therefore, we decided to retain S1001 over S1016.

S1016 had also 5 blocks overlapping with S1008. The S1016 values were accepted as their 1° averages were more consistent with June 1986, BGI and Watts et al (1985) values. We should note that 1 mgal was added to the accuracy estimates of S1001 which had a truncation error in the prior determination.

4.5.3 Source 1024

For the blocks overlapping with S1016, source S1024 used more point values to average 30′ mean values than S1016, i.e., the accuracy of this source was better than that of S1016. (The RMS accuracy of S1024 and S1016 was 8 mgal and 13 mgal respectively). 1° anomalies from this source were more consistent with BGI and Watts et al (ibid) values than those of S1026. However, some blocks in S1024 had too few point values so that S1016 values had better accuracies and must be retained. F292K was run for selecting the appropriate value with the standard criteria.

4.5.4 Source 1029

This source had an excellent agreement with S1001 (data in South Africa) on land having an estimated RMS difference of approximately 3 mgal. In sea areas, S1001 was more consistent with the altimeter derived anomalies which had predicted accuracies of 3 to 4 mgal. Though S1029 was said to be the compilation of all available private and public domain gravity data (Lamont Newsletter, 1989), it was still reasonable to retain S1001 over S1029 for the consistency purpose for the area S1001 covers.

Many blocks of S1029 had the number of point values used to calculate 30′ mean values exactly the same as those of S1024, which implies that S1029 may contain S1024 as discussed earlier. As those two sources were in good agreement with an estimated RMS accuracy of 7 ~ 8 mgal, we decided to retain S1024 over S1029.

S1029 had a smaller RMS standard deviation (9.0 mgal) than S1016 (13.5 mgal). Furthermore, the RMS difference between S1029 and the 1989 altimeter anomalies was 12.3 mgal while that between S1016 mgal and S1001 was 20.1 mgal. Considering the altimeter anomalies and S1001 values were very reliable with estimated RMS standard deviations of 3 ~4 mgal and 5 mgal respectively, we could give more reliability to S1029 and we accepted S1029 over S1016.

Source 1035 had many values in the Mediterranean Sea where S1004 and S1014 were available. The F292K run against these sources showed many blocks with large discrepancies.

Comparison of 1989 altimeter derived anomalies with the old and new sources showed inconsistencies among them though most S1004 and S1014 values were consistent with the altimeter values. Therefore, we started questioning the reliability of all these sources including the altimeter data which might have poor values near shore and in areas of rapid anomaly change.

Responding to a letter dated 5/25/89 sent by Rapp regarding the problem discussed above, Fairhead, of the African Gravity Project, indicated that the Mediterranean Sea was not well sampled except for some limited areas in his letter dated 6/6/89. Further information sent by Arabelos in a letter dated 5/10/89 also responding to a request by Rapp, gave 235 30′ mean values in the Eastern Mediterranean, which were eventually adopted as a new source, S1032.

Table 1 shows comparisons among S1004 (or S1014), S1029, altimeter anomalies (1989), and S1032. From this table, we can see the standard selection procedures of the F292K worked fine in the sense that the selected values are consistent with S1032 values. Therefore, we ran F292K without any further modification of "human choice" to create a file containing the best values in Mediterranean area. The decisions implemented in the F292K run for this source were as follows:

A. Retain S1001 values
B. Retain S1024 values
C. Choose S1029 values over S1016 values

4.5.5 S1032

As discussed in the previous section, this source was originally used to check if the best values were chosen in the F292K run for S1029. Meanwhile, we also see from Table 1 that values from this source agree well with altimeter values of the blocks which does not agree with either S1004 or S1014 or S1029. In addition this source has a number of values not present in other sources. Therefore, we decided to use this source following the standard criteria of program F292K.

4.6 Sources for Far Eastern Asia

For this region, S1006 was available from the August 1986 field. S1023 was introduced at update 2, and S1027 and S1030 at update 3. S1023 had 1 common block with S1030 and no common value with S1029.

4.6.1 Source 1023

This source has two different 30′ mean data sets: one is from a free-air anomaly map by Liu and the other one is from the averaging of 10′ mean values provided by Chang. For some blocks near shore, neither source gave sufficient coverage to calculate 30′ mean values. Therefore, altimeter derived (1989) anomalies were used as a supplementary source near shore. We now call the combination of Chang's data and the altimeter data as S1023A and of Liu's data and the altimeter anomalies as S1023B for convenience.

A comparison of S1023A and S1023B showed a root mean square difference of 11.6 mgal excluding two 30′ blocks with large differences. For these two blocks, the anomalies from S1023A were unreasonable considering the elevations of the cells and the anomalies in the adjacent blocks. However the S1023B were reasonable for these two cells.

Both S1023A and S1023B were compared to S1006 revealing large discrepencies in some cases. Both S1023A and S1023B seemed to be comparable sources in terms of accuracy. Due to the apparently reliable estimates for the two special blocks we selected S1023B for the final data file.

Table 1. Comparison of 30′ Mean Free-air Anomalies from Various Sources in the Eastern Mediterranean. (Anomaly units are in mgal.)

Block Coordinates (N.W. Corner) ϕ	λ	Δg (σ) S1004 or S1014 *	Δg (σ) S1029	Discrepancy S1004 or S1014 -S1029	Δg (σ) Altimetry 1989	30′ x 30′ Elevation TUG87 (m)	Δg (σ) S1032
37.0	31.5	19.5 (3)	-49.3 (15)	68.8	—	76	18.9 (31)
36.5	26.5	*82.1 (11)	46.8 (14)	35.3	75.7 (4)	-651	65.2 (27)
36.5	30.0	-58.9 (3)	-127.3 (11)	68.4	-61.0 (7)	-602	-74.2 (45)
36.5	32.0	13.7 (3)	-28.5 (11)	42.2	14.5 (7)	-414	12.0 (40)
36.0	26.0	*43.5 (10)	-15.3 (2)	58.8	15.3 (4)	-1312	20.9 (54)
36.0	26.5	*15.2 (5)	-60.8 (8)	76.0	4.2 (4)	-1262	-8.1 (77)
36.0	28.0	*-68.8 (9)	-140.6 (9)	71.8	-122.2 (5)	-2950	-132.1 (46)
35.0	27.5	*-97.2 (10)	-143.6 (9)	46.4	-145.4 (4)	-2564	-133.0 (27)
35.0	31.0	-96.0 (5)	-122.8 (9)	26.8	-113.8 (5)	-2334	-114.7 (13)
35.0	32.5	109.8 (3)	141.8 (9)	-32.0	—	-233	113.4 (85)
35.0	33.0	92.9 (3)	131.6 (9)	-38.7	47.5 (8)	-204	95.3 (94)
34.5	29.0	-58.0 (5)	-82.0 (7)	24.0	-97.4 (5)	-2800	-82.1 (8)
34.0	26.5	-126.6 (3)	-156.6 (11)	30.0	-155.1 (4)	-2628	-141.0 (35)
33.5	27.5	-71.6 (3)	-94.6 (8)	23.0	-79.6 (4)	-2985	-81.6 (33)
32.5	26.0	-80.4 (3)	-102.8 (8)	22.4	-89.4 (4)	-2945	-84.7 (10)
31.5	28.0	-22.0 (5)	1.6 (2)	-23.6	-38.2 (5)	-781	-29.2 (9)

4.6.2 Source 1027

Of the 57 30′ values in this source two were based on extrapolation and therefore were deleted. The 55 anomalies were compared to S1006 where a mean difference of -1.1 mgal, and a root mean square difference (RMS) of ±12 mgal, were found. The 1° x 1° averges formed from the 30′ values showed excellent agreement with other estimates (June 1986 1° values, BGI (1988), Watts et al. (1985)). This source had two common values with S1030 in a coastal region. The S1027 values agreed better with the altimeter derived (1989) anomalies. We decided to accept S1027 over S1006 and S1030.

4.6.3 S1030

The F292K run for 30′ mean values calculated by simply averaging the original 5′ mean values showed large a mean difference and a large RMS differences with the altimeter derived (1989) anomalies values as shown in Table 2. Furthermore, considering the sea data of S1030 were prepared by the same organization which sent S1006, we presumed that the mean difference of 5.8 mgal and the RMS difference of 15.3 mgal were unacceptably large. Careful review of the F292K run which now listed only blocks with large discrepancies (30 mgal) revealed that the magnitude of discrepancies might be related to the difference between TUG 87 and 30′ mean elevations computed from S1030 data.

To consider the elevation differences the free-air anomalies were corrected taking into account the difference between the computed 30′ elevation ($\overline{H}$) and the TUG87 30′ elevation, H_T. Pavlis used the following equation:

$$\Delta g_c = \Delta g - c\left(\overline{H} - H_T\right) \tag{11}$$

where Δg was the 30′ average from the 5′ values. In the case of land areas c was set to 0.1119 mgals/m while in ocean areas it was set to 0.06886 mgal/m. The corrected 30′ anomaly file was created by Pavlis and stored as TS4757.S1030.COR1. This corrected file was compared to the anomalies of S1006 and to the altimeter derived anomalies. These results are shown in Table 3. On land the RMS difference was still large (± 13.2 mgal) which was primarily due to three cells which were later corrected. In this case the discrepency was reduced to 8.0 mgal.

The results seen in Table 3 for the ocean areas and comments in a letter of 3/20/89 from Segawa led us to use the above equation for land areas and to study further the ocean areas.

In the next step Pavlis carried out an adjustment to solve for a bias and slope term in the anomalies considering the elevation discrepencies in the ocean areas. The adjustment that was carried out using 41198 5′ x 5′ cells gave a slope of 0.01216 mgal/m. A corrected source file (TS4757.S1030.COR2) was created with this slope in the ocean areas and the normal slope (0.1119) in the land areas. Comparisons with the altimeter anomalies showed a RMS difference of 17.4 mgal (see Table 3). As this was still poor we decided to keep the original ocean anomalies. The modified data set was then used in F292K letting the program select the best value using the built-in criteria. In summary the final decisions for this source were as follows:

A. Divide S1030 into a land and sea part;
B. Add the correction of equation (11) to the land part and when the F292K is run, add 2 mgals to the standard deviation of S1006 as the accuracy of S1006 was thought to be too optimistic.
C. Use the original sea part of S1030 as input for the F292K run.

Table 2. Comparison of 30′ Values of Original S1030 with S1006 and the 1989 Altimeter Derived Anomalies

	S1030 - S1006 (land and sea)	S1030 - S1006 (land only)	S1030 - Altimeter (89)	S1006 - Altimeter (89)
Number of 30′ blocks	2323	170*	2184	2421
Mean difference (mgal)	5.8	-7.6	-10.2	-4.2
RMS difference (mgal)	15.3	13.8	17.8	13.7

*a block common with a value of S1023 is not included but no difference in statistics is expected as S1030 value - S1023 value = - 8.8 mgal.

Table 3. Comparison of 30′ Values of Corrected S1030

	S1030 - S1006 (COR1, land only)	S1030 - S1006 (COR1+3 changes) (land only)	S1030 - Alt 89 (COR1)	S1030 - Alt 89 (COR2)
Number of 30′ blocks	171	171	2184	2184
Mean difference (mgal)	1.3	0.0	-9.1	-10.0
RMS difference (mgal)	13.2	8.0	22.0	17.4

4.7 Sources for Other Geographic Areas

4.7.1 Source 1012 - Australia

The F292K run of this source against S1003 of the August 1986 field showed that S1012 was not consistent with S1003 for the blocks in coastal regions although S1003 agreed well with the 1985 altimeter anomalies. The overall agreement between S1012 and S1003 was good (RMS difference = 9.4 mgal, mean difference = 1.0 mgal). The agreement on land was particularly good (RMS difference = 4.8 mgal, mean difference = 0.8 mgal).

S1012 had 90 new values with respect to S1006 but most of them were in coastal regions where they were thought to be poor. Therefore, we decided to retain S1003 and not to use S1012 at all even though the values were from a new computation but not necessarily new point data.

4.7.2 Source 1031 - Sri Lanka

This source had no common value with any in the August 1986 field. Seven blocks near shore had common values with the 1989 altimeter anomalies. The differences were acceptable for the coastal region. Therefore, we decided to accept all values of this source.

4.7.3 Source 1017 - Malaysia

This source had no common value with any in the August 1986 field. Two blocks near shore had common values with the altimeter anomalies (1989), with differences of 1.5 mgal and -19.1 mgal which were reasonable for the shore blocks. All values of this source were accepted.

4.7.4 Source 1018 - Hawaiian Island Area

As noted in Section 3.8 this source actually consisted of three candidate sources: S1018W; S1018NF; and S1018NB. As large discrepancies existed among these files, 1° x 1° averages were formed for comparison with other (June 1986, Watts et al (1985), BGI (1988)) values. It was found that S1018W was more consistent with the other values although the anomalies of S1018W were systematically high by 8 mgal. Therefore, S1018W, with 8 mgal subtracted, was used in a F292K run. After comparisons with both 1985 altimeter anomalies and the more reliable (in this area) 1989 anomalies it was decided to accept all S1018W values with 8 mgals subtracted, with the standard deviation modified in the ocean areas according to the standard criteria. One ocean anomaly at $\phi = 21.0$, $\lambda = 204.0$ was rejected because of its poor data coverage and its significant disagreement with the 1985 altimeter derived anomaly.

In this analysis it was found that S9 of the August 1986 file should have been S10 in this region. A correction was made for this in update 1.

5. The Formation of the 1° x 1° and 30′ x 30′ Files

5.1 Introduction

The previous sections have described the new data sources that were to be used in creating a new 30′ anomaly data file. Before forming the final update we wanted to be sure that the 1° x 1° anomalies formed by averaging the 30′anomalies were reasonably consistent with existing 1° x 1° data files. The two major 1° x 1° files were the June 1986 file and a set provided in May 1989 by the Defense Mapping Agency Aerospace Center. This latter data source contained 45054 anomalies and their accuracy. Of these anomalies 6265 values were computed through geophysical correlation techniques (Wilcox, 1974).

The development of the new 1° x 1° and 30′ x30′ files was carried out in an iterative fashion depending on what data might be deleted from the 30′ files due to questions on the reliability of the anomaly. The procedures followed are described in the next sections. The updates were to be known as the July 1989 fields. However, it became necessary to specify specific dates associated with these updates as several were carried out. Therefore references to a July 13, 1989 update (as well as other dates) will be found in the following.

5.2 The 1° x 1° Updates

The formation of the July 1989 1° x 1° field took place in three steps. The first step was to form 1° x 1° average anomalies from the 30′ x 30′ anomalies in the updated 30′ file which was file 16 of tape GS327. (Note that file 16 is a revised version of file 15 with 1000 added to all source numbers in file 15.) This led to the formation of the preliminary July 89 1° x 1° field. The 1° x 1° anomaly (Δg_{1°) and its accuracy were calculated using the following equations:

$$\Delta g_{1^\circ} = \frac{\sum^{N} \Delta g_{30'}}{N} \tag{12}$$

$$\sigma_{1^\circ} = \sqrt{\frac{\Sigma\, \sigma_{30'}}{N}} + (4 - N) * 3 + 0.5\,(\text{mgal}) \tag{13}$$

where:

σ is the accuracy of the 1° or 30′ anomaly;

N is the number of the 30′ anomalies within the 1° block.

The equation for σ_{1° was an empirical equation which was later found to give pessimistic values for σ_{1° in the preliminary 1° updates. Note that all σ values are taken to be integers. The anomaly file that was created was merged with the TUG87 elevation file and stored as file 8 on GS322 with a data set name of ONEDEG.FROM.THIRTY.

We found, through comparisons of the June 1986 file and a DMA87 file (DMAAC87 was a prior version of the DMAAC89 file) that certain geophysically predicted anomalies in the June

1986 were incorrectly identified. A corrected 1° x 1° file was created which incorporated the updated 1° x 1° elevation file (Wieser, 1987). The corrected and revised data set was written as file 3 on tape GS322 by Despotakis. The data set name was JUN86.TUG87.DMA87.

The second step in the update process was the merger of the modified June 86 file with the DMAAC89 data to create file 7 of GS322 with the data set name JUN86.MER.DMA89. The merging process took place using the same criteria used by Despotakis (1986, page 12) when the June 1986 file was being developed. The summary of the criteria is as follows where 1985 1° x 1° altimeter anomalies were used for comparison purposes:

1. If an OSU value is from an old DMAAC source, the new DMAAC value is chosen.

2. If an OSU value is a geophysically predicted value, the DMAAC value is accepted.

3. If an altimeter anomaly is not available (e.g. a land anomaly), or if the accuracy of an available altimeter anomaly is ≥ 10 mgals, the terrestrial estimate with the smaller standard deviation is accepted but giving a 2 mgal preference to the OSU values (i.e. June 1986 1° standard deviation). Specifically, preference means if an OSU anomaly has an 8 mgal standard deviation and a DMAAC value has a 6 mgal standard deviation, the OSU value is chosen, assuming no or unacceptable altimeter anomalies.

4. If an altimeter anomaly is available with an accuracy < 10 mgal, we form two sums:

   A. |OSU value-altimeter value| + OSU standard deviation

   B. |DMAAC value-altimeter value| + DMAAC standard deviation.

The value with the smaller sum is accepted. If the sums are equal, the DMAAC is chosen. In case A, if the standard deviation of the OSU value is greater or equal to 6 mgal, we give a modified standard deviation, to the accepted anomaly:

$$\sigma = \text{Max}\,(6, |\text{OSU value-altimeter value}|) \tag{14}$$

The final step was the merger of ONEDEG.FROM.THIRTY (file 8, GS322) with the JUN86.MER.DMA89 data. Two versions (essentially an iteration) of this merger are described in the following sections.

5.2.1 The July 13, 1989 Update

Two 1° x 1° updates were ultimately to be carried out with the first called the July 13, 1989 update. It was created by merging the June 86/DMAAC89 data (file 7 of GS322) with the preliminary July 1989 1° x 1° values (file 8 of GS322) computed form the 30′ x 30′ data. The merging program was modified to list the blocks whose values, chosen from JUN86.MER.DMA89 (file 7, GS322) had large (≥25 mgal) discrepencies between the two fields. We considered such cells as significantly inconsistent. To attack the inconsistency problem, we made various attempts to examine some possible bad values of the preliminary JULY89 1° field. The list of problem blocks showed that they had generally large standard deviations. Therefore, we might have deleted values with large standard deviations. However, an attempt to do this resulted in the deletion of many values of the JULY89 1° field.

After further examinations of the problem blocks, we found the standard deviations of the preliminary JULY89 1° field were too pessimistic and we tried a new formula as follows:

$$\sigma_{1^\circ} = \frac{\sqrt{\Sigma \sigma_{30'}}}{N} + (4 - N) * 3 + 0.5 \quad \text{(mgal)} \tag{15}$$

where the notation is the same as in formula (13).

We also decided to add the following criteria to the programs merging the preliminary JULY89 1° field with the JUN86.MER.DMA89 file:

A. in sea areas, accept the preliminary JULY89 1° field without comparing with altimeter data if

$$\left| \Delta g_{89} - \Delta g_{86} \right| \leq \text{Max}\,(5, X) \tag{16}$$

where Δg_{89} is the preliminary JULY89 1° field value, Δg_{86} is the JUN86.MER.DMA89 value (file 7, GS322), and:

$$X = \left| \text{Max}\,(\Delta g_{89}, \Delta g_{86}) \right| * 0.1$$

B. on land, accept the JULY89 1° field if

$$\left| \sigma_{89} - \sigma_{86} \right| \leq \text{Max}\,(5, Y) \tag{17}$$

where

σ_{89} is standard deviation of the preliminary JULY89 1° field

σ_{86} is standard deviation of the JUN86.MER.DMA89

$Y = \text{Max}\,(\sigma_{86}, \sigma_{89}) * 0.3$

With these criteria we could avoid losing many values of the preliminary JULY89 1° field which were reasonably good accepting the fact that the accuracy estimates of the June 86 1° field might have been too optimistic.

Meanwhile, as we found that the 1° average value of some blocks of the August 1986 30′ field agreed much better with the June 1986 1° field than the preliminary JULY89 1° values, we replaced 12 values of S1011 with corresponding values from the source S1002. We also deleted 2 values from S1018 as they were not consistent with values from any other sources.

With the decisions discussed so far, we created file 8 of tape GS322 with DSN = ONEDEG.FROM.THIRTY which would be used as the final preliminary JULY89 1° field. We also created file 17 of tape GS327 by deleting 2 30′ values and replacing 30′ 12 values. This 30′ file is the final preliminary JULY89 30′ field.

We then ran the modified merging program to list the problem blocks when merging the ONEDEG.FROM.THIRTY with the JUN86.MER.DMA89 data file. The number of problem 1° blocks were significantly decreased as desired. The corresponding 30′ values were removed from file 17 of tape GS327 to create the file 18 (DSN=TERR.HALFDEG.TUG87.JULY1389). Then the values of that file were averaged to form the semi-final version of the JULY1389 1° field which was written on file 9 of tape GS322 with DSN = ONEDEG.FROM.THIRTY.JULY1389.ELEV.

Finally, we merged the last 1° file (file 9, GS322) with the JUN86.MER.DMA89 file with the same criteria discussed in this section. In that merging run, 3 1° values (at ϕ/λ equal to 28°, 94°; 28°, 95°; and 27°, 94°) were replaced with new empirical estimates. The source I.D. code for all DMAAC data was specified as 1.

The resulting file is the final JULY1389 1° field written on the file 10 of tape GS322 with DSN = TERR.ONEDEG.TUG87.JULY1389. As we removed problem blocks, no such blocks were listed in the final merging run. File 10 (GS322) had incorrect estimation method codes as did a starting file (file 3, GS322). The correction of this code problem was made in the next version of the 1° update. The method codes may be found in Appendix C.

We should note that by removing problem blocks directly from file (GS322) 8 of the final preliminary JULY89 1° file, we would have saved some steps. However, to create the 30′ field without problem blocks and to make sure steps taken to remove those blocks were correctly done, we took additional steps as described earlier.

5.2.2. JULY21, 1989 Update - The Final Version of the 1° x 1° Update

The JULY1389 1° field was compared with the JUN86 1° field of file 1 of tape GS322 by running the F305BV1 program. The run showed there were many blocks with large discrepancies between DMAAC '85 (the DMAAC values in the June 86 data set) and DMAAC '89 1° values. In our JULY13 update, we automatically chose the DMAAC '89 values over DMAAC '85 values as we believed the new version of the DMAAC values were more reliable. However, when we compared these values with altimetry derived values when available, we found that the DMAAC'85 values agreed better than the DMAAC'89 values for some cases. That fact implied that some DMAAC '89 values might be bad, and the criterion to choose DMAAC '89 values over DMAAC '85 values should be re-examined.

Since we had reliable altimeter derived anomalies we choose in a new merger procedure the DMAAC value that was closest to the altimeter value. In land areas the DMAAC 89 value was the preferred (over DMAAC85) values. This new criterion was coded in the merging program TS4757.F292C#MER3N2, which merged DMAAC '89 values with the JUN '86 1°field. Meanwhile, in the JULY1389 update, we used file 3 of tape GS322 as the JUN86 1° field file. However, we found that file had wrong estimation method codes so that we decided to use TS0040.JUN86.TUG87.DMAMOE87 (created by Pavlis) instead which had the correct method codes. The DMAAC '89 values now were given the new source code, 96. The resulting file was then written on file 11 of tape GS322 with DSN = ONEDEG.MER3.NEW21.JULY2189. This file was merged with file 8 of tape GS322, DSN = ONEDEG.FROM.THIRTY to create the merged file which was later written as file 12 of tape GS322. That run also gave the list of problem blocks. Then the 486 30′ values used in the computation of the problem blocks were deleted from file 17 of tape GS327 and the final file of the JULY2189 30′ field was written as file 19 of tape GS327 with DSN = TERR.HALFDEG.TUG87.JULY2189.

Anomalies on file 19 (GS327) were averaged to create the semi-final file of the JULY2189 1° field after adding TUG87 1° elevations and the result was written as file 13 of tape GS322 (DSN = ONEDEG.FROM.THIRTY.JULY2189.ELEV). Finally, merging file 13 with file 11 of tape GS322, we created the final JULY2189 1° field which, then was written on file 14 of tape GS322 with DSN = TERR.ONEDEG.TUG87.JULY2189.

Table 4 shows comparisons between the JULY13 and JULY21 1° update. As the result of the new criterion to choose values closer to the altimetry derived values in sea areas, 1797 less values were chosen from DMAAC 89 values. Furthermore, as we now have more reasonable values in

JUN86.MER.DMA89 (file 7, GS322), 86 fewer values were taken from ONEDEG. FROM.THIRTY (file 8, GS322) which had some problems blocks as described earlier.

Table 4. Comparison Between JULY13 and JULY21 1° Update

	July13 Update	July 21 Update
Merging JUN86 with DMA89 (1°)		
From DMAAC '89	31854	30057
From file 3, GS322	18469	
with correct method code		20266
File 3 values preferred	13200	14997
Add'l values not on file 3	5269	5269
Placed on merged file (*)	50323	50323
Merging 1° from 30′ ('89) with JUN86.MER.DMA89		
From JUN86.MER.DMA '89	32581	32667
ONEDEG.FROM.THIRTY preferred	17742	17656
Add'l values not in JUN86.MER.DMA '89	470	470
Number on merged file (**)	50793	50793
Mean difference between * and **	0.6 mgal	0.6 mgal
RMS difference between * and **	11.6 mgal	11.6 mgal

5.3 Summary of the July 1989 1° and 30′ File Creation

5.3.1 JULY13, 1989 Update

Schematic Summary with Key Runs, Programs, Data Sets Names, and Tape Numbers

F292C.MER31
TS475793

DMAAC 89
JUN86 (file 3, GS322, with correct geophysical codes)
Altimeter anomalies (1985) as check

* created → TEMP.ONEDEG.MER3

→ file 7. GS322 DSN=JUN86.MER.DMA89

↓

COMPO.GLOBAL3
TS475727

* 1° from 30' blocks
* created TS4757.TEMP72.ONEDEG.FROM.THIRTY
* adding TUG87 elevation gave TS4757.ONEDEG.FROM. THIRTY.ELEV which was written as file 8, GS322, DSN=ONEDEG.FROM.THIRTY

↓

F292C.CHEK.JUL12
TS475729

* identifying problem blocks when merging TS4757.TEMP72.ONEDEG.FROM.THIRTY.ELEV with JUN86MER.DMA89 (file 7, GS322)
* new criteria used

↓

Runs by Pavlis

* deleting 30' problem block values from file 17, GS327, DSN=TEMP72.COR.JUL12
* created TS0040.TERR.HALFDEG.TUG87.JULY1389
  → file 18, GS327; DSN=TERR.HALFDEG.TUG89. JULY1389

↓

COMPO.GLOBAL3K
TS475741

using
* TS0040.TERR.HALFDEG.TUG87.JULY1389 calculated 1° average file
* created: TS4757.ONEDEG.FROM.THIRTY.JULY1389
+ TUG87: TS4757.ONEDEG.FROM.THIRTY.JULY1389.ELEV
→ file 9 GS322; DSN=ONEDEG.FROM.THIRTY.JULY1389.ELEV

↓

F292C.MER79.JUL13
TS475764

* merging TS4757 ONEDEG.FROM.THIRTY.JULY1389.ELEV with JUN86.MER.DMA89 (file 7, GS322)
* and adding 3 blocks (S95)
  DMAAC code = 1
* created TS4757.TERR.ONEDEG.TUG87.JULY1389
→ file 10, GS322; DSN=TERR.ONEDEG.TUG87.JULY1389

5.3.2 JULY21, 1989 UPDATE

Schematic Summary with Key Runs, Programs, and Data Sets

F305BV1 TS475728	* provided clues to find DMAAC89 had some poor values
↓	
F292C#MER3N2 TS475743	* Merging DMAAC '89 with TS0040.JUN86.TUG87.DMAMOE87 A new criterion to avoid choosing poor DMA89 values in sea areas. DMAAC89 source code is 96 * Created TS4757.TEMP.ONEDEG.MER3.NEW2 → file 11, GS322: DSN=ONEDEG.MER3.NEW21.JULY2189
↓	
F292C#CN2 TS475755	* Identifying problem blocks when merging TS4757.TEMP72.ONEDEG.FROM.THIRTY.ELEV with TS4757.TEMP.ONEDEG.MER3.NEW2
↓	
Runs by Pavlis	* Deleting problem block values from file 17, GS327: DSN=TEMP72.COR.JUL12 * Created TS0040.TERR.HALFDEG.TUG87.JULY2089 → file 19, GS327: DSN=TERR.HALFDEG.TUG87.JULY2189
↓	
COMPO.GLOBAL TS475767	* Using TS0040.TERR.HALFDEG.TUG87.JULY2089, calculate 1° file * Created TS4757.ONEDEG.FROM.THIRTY.JULY2189 * adding TUG89 elevation → TS4757.ONEDEG.FROM.THIRTY. JULY2189.ELEV → file 13, GS322: DSN= ONEDEG.FROM.THIRTY.JULY2189. ELEV
↓	
F292C.MER79N2 TS475786	* Merging TS4757.ONEDEG.FROM.THIRTY.JULY2189.ELEV with TS4757.TEMP.ONEDEG.MER3.NEW21 * created TS4757.TERR.ONEDEG.TUG87.JULY2189 → file 14, GS322: DSN=TERR.ONEDEG.TUG87.JULY2189

5.4. Statistical Analysis of the July 1989 30′ and 1° Field

5.4.1 JULY 1989 30′ Field

The total number of anomalies of the JULY 1989 30′ field placed on file 19 of tape GS327 is 66990. The location of these values are shown in Figure 25. Various symbols are used to distinguish values from different sources. Substantially more (35203) values are now in the new field than were in the August 1986 field. The locations of these new values are shown in Figure 26. Table 5 gives statistical information for the July 1989 and August 1986 30′ field and Table 6 shows statistics of the difference of these two fields. The mean value is reduced to 0.1 mgal from -3.0 mgal in the August 86 field, and the weighted mean value is reduced to 0.3 mgal from 2.4 mgal. No significant change in the RMS values is found. The RMS standard deviation is increased to 9.4 mgal from 5.7 mgal. This is partly due to new sources with larger standard deviations and partly due to replacing the August 86 standard deviations with larger standard deviations due to more realistic accuracy evaluations.

The mean difference between two fields is 0.5 mgal and the RMS differences is 10.3 mgal, which indicates a reasonably good agreement between them. Figure 27 shows the location of the 1025 blocks (out of 31787) where the difference between the two files is ≥ 20 mgals. Heavy concentrations of these blocks are observed in the Rocky Mountains of Canada, the California peninsula and Mexico. The analysis of new sources for these areas showed the new sources should be more reliable than the old source S1002. Table 7 shows some blocks of large discrepancies between new and old fields. Table 8 shows the number of anomalies used from each source in the July 1989 final 30′ anomaly update.

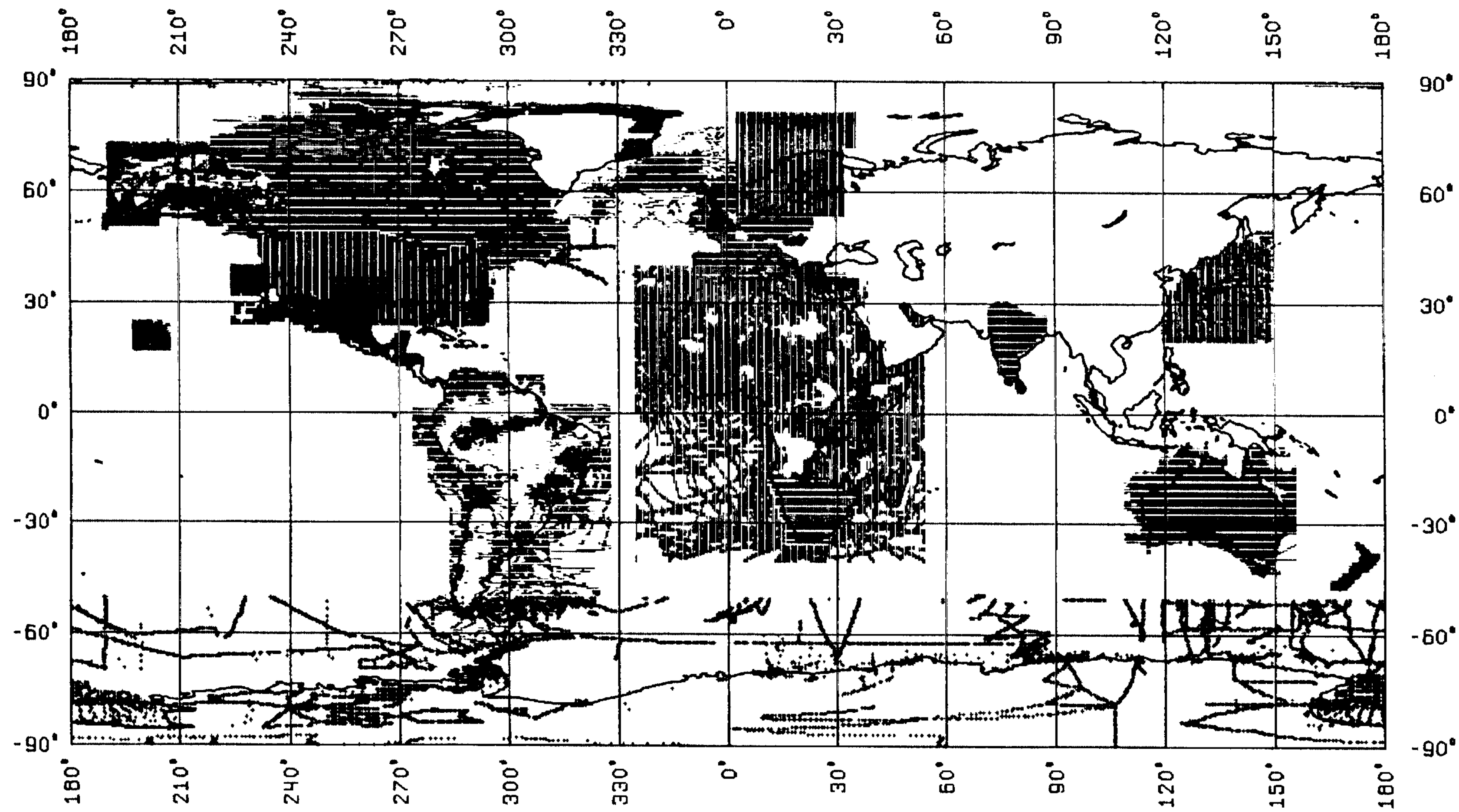

Figure 25. Location of 66990 30′ Anomalies in the Final July 1989 Update (file 19, GS327)

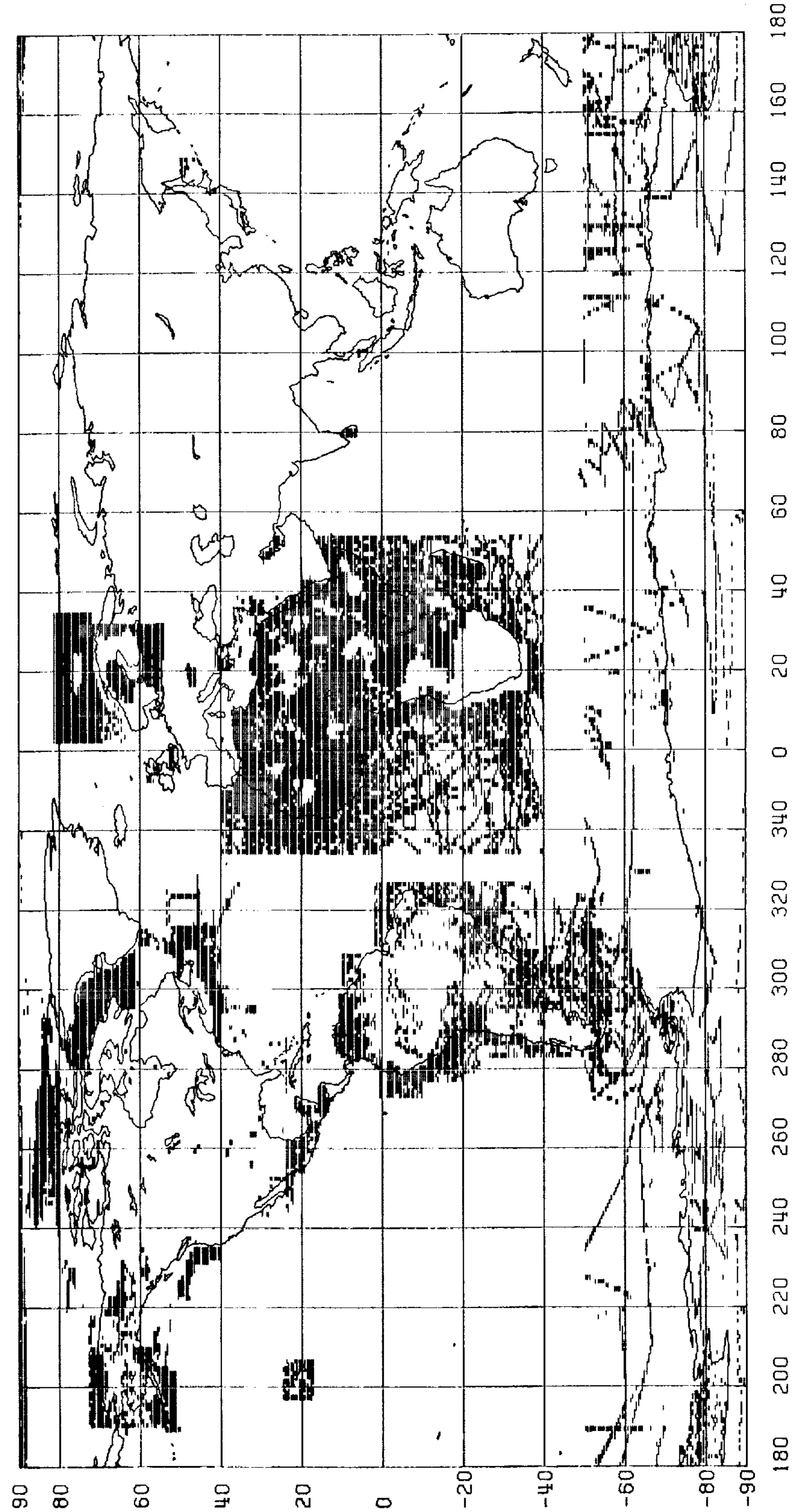

Figure 26. Location of 35264 30' Anomalies in the July 1989 file that were not in the August 1986 File

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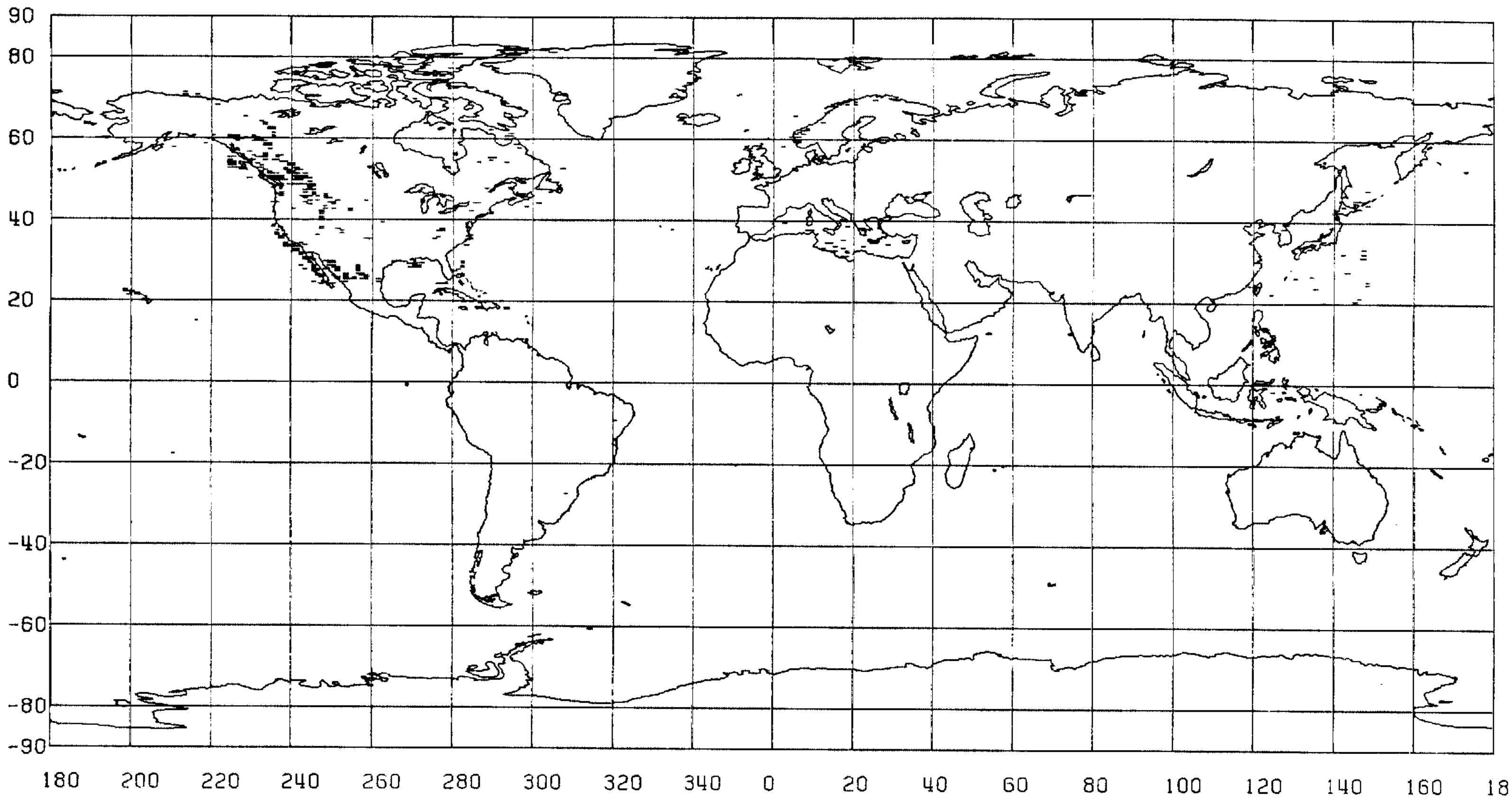

Figure 27. Location of 1025 30′ Blocks Where the Difference Between the August 1986 and July 1989 Files is ≥ 25 mgal

Table 5. Statistical Information for the August 1986 and the July 1989 30′ x 30′ Field (Units are mgal.)

	Northern Hemisphere		Southern Hemisphere		Global	
	JULY 1989	AUG 1986	JULY 1989	AUG1986	JULY 1989	AUG 1986
No of Anomalies	42830	25107	24160	6619	66990	31787
Mean value	-0.2	-4.4	0.7	2.4	0.1	-3.0
RMS value	31.9	33.7	32.2	26.7	32.0	32.4
Min value	-283.5	-349.7	-209.0	-184.7	-283.5	-349.7
Max value	382.0	321.7	302.6	142.6	382.0	321.7
Wdt. mean*	-0.4	-4.3	1.4	2.6	0.3	2.4
Wdt. RMS*	32.3	34.6	31.9	26.5	32.2	32.6
Min σ	2	2	1	0	1	0
Max σ	46	21	37	21	46	21
RMS σ	7.5	5.6	12.0	6.0	9.4	5.7

* cosine ϕ weighting

Table 6. Statistics of JULY 1989 30′ - August 1986 30′ Anomaly Data

	Northern Hemisphere	Southern Hemisphere	Global
No. of common values	25107	6619	31726
Mean difference	0.3	1.0	0.5
RMS difference	11.6	1.5	10.3
Min difference	-220.5	-48.3	-220.5
Max difference	309.0	21.9	309.0

Table 7. Some Large 30′ Anomaly Discrepancies (August 1986 vs July 1989)

ϕ (°)	λ (°)	Old Value in mgal (Source I.D.*)	New Value in mgal (Source I.D.)	Difference in mgal (Old-New)
54.0	225.5	-326 (2)	-48 (1036)	-278
53.5	225.5	-323 (2)	-14 (1036)	-309
53.5	226.0	-350 (2)	-56 (1036)	-294
28.5	271.5	-234 (2)	-43 (1011)	-192
28.5	272.0	-261 (2)	-66 (1011)	-195
24.0	121.0	45 (6)	186 (1023)	-142
21.5	203.5	120 (9)	-16 (1018)	136

* 1000 has been added to the Source code in the 30′ July 89 field

Table 8. Number of Anomalies by Sources in the July 1989 30′ Update

Source	Number of Anomalies
1001	1368
1002	1326
1003	4491
1004	3530
1005	543
1006	2060
1007	737
1008	841
1009	174
1010	0
1011	4026
1012	0
1013	103
1014	155
1015	0
1016	447
1017	17
1018	260
1019	1376
1020	27
1021	643
1022	3414
1023	15
1024	183
1025	54
1026	6610
1027	55
1028	105
1029	14761
1030	606
1031	26
1032	37
1033	90
1034	330
1035	108
1036	12676
1037	925
1038	4871
Total	66990

5.4.2 July 1989 1° Field

The total number of anomalies in the July 1989 1° field placed on the file 14 of tape GS322 is 50793. The location of these values is shown in Figure 28. The location of the 5667 geophysically predicted anomalies and the 45126 non geophysically predicted anomalies are shown in Figure 29 and 30 respectively. The locations of the 23515 values from DMAAC and the 27278 values of non DMAAC sources are shown in Figure 31 and 32 respectively. The location of the 5837 anomalies with standard deviations of ≥ 20 mgal are shown in Figure 33.

Figure 34 shows the locations of 1838 new values in the July 1989 field which were not available in the June 1986 field. Table 9 shows statistical information for the July 1989 and the June 1986 field and Table 10 shows statistics of the differences of these two fields. The mean value is reduced to -0.5 mgal in the new field from -1.4 mgal in the old and the weighted mean value is also reduced to -0.5 mgal from -1.3 mgal. The RMS standard deviation is reduced to 13.5 mgal from 14.2 mgal. The mean difference and RMS difference are 0.7 mgal and 8.0 mgal respectively, which indicates good agreement between the two fields. Figure 35 shows the location of 1478 values with differences ≥ 20 mgal between two fields. The greatest number of blocks with large discrepancies occurs when the source of the old field is 1 which is from DMAAC before 1989. This fact can be found from the F305BV1 run which creates the statistics of the two 1° fields. Table 11 shows some of the large discrepancies between the new and old 1° fields.

The number of anomalies by sources are given in Table 12. When no value form a source is used, that source is omitted from the table.

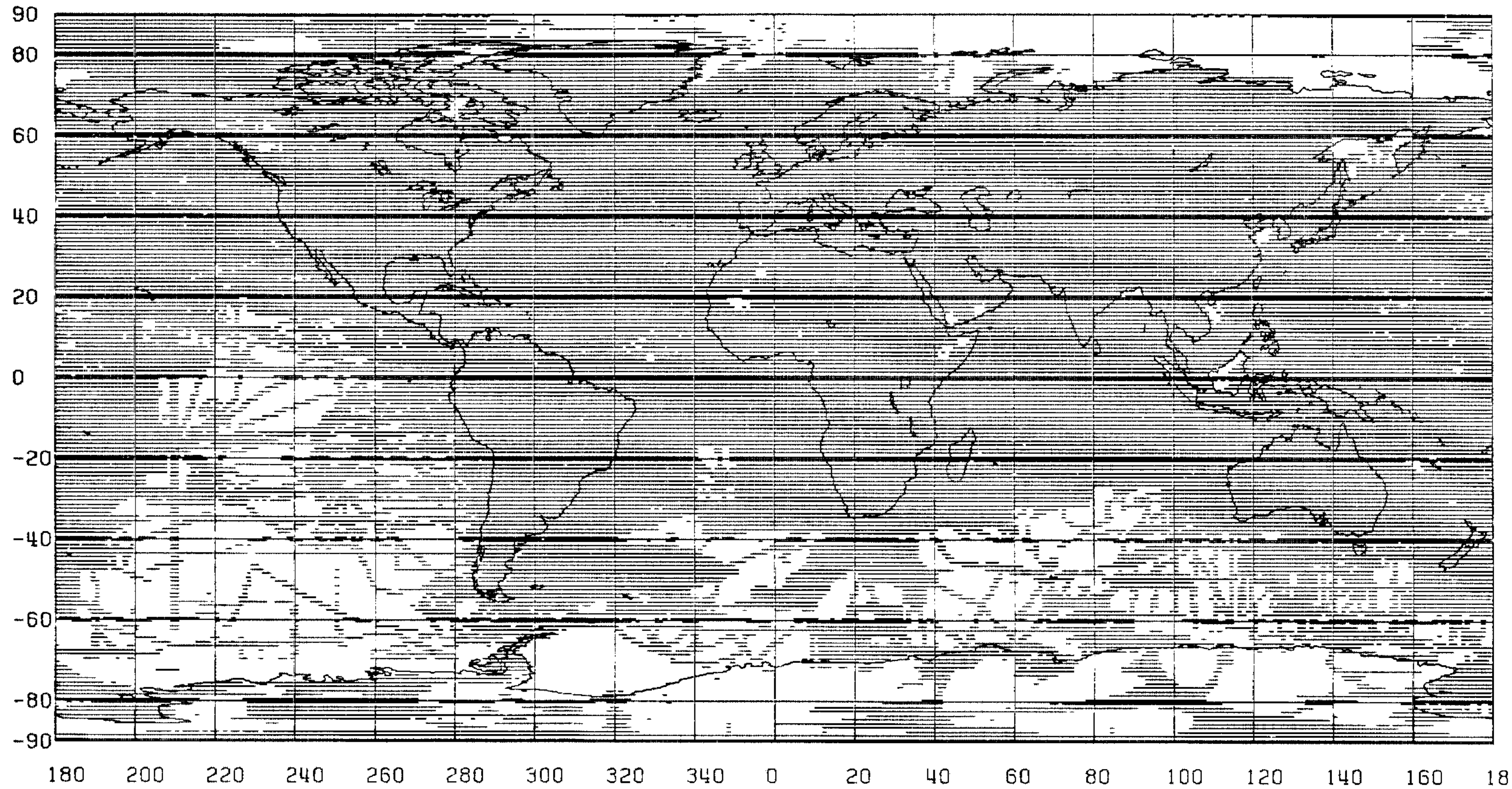

Figure 28. Location of 50793 Anomalies in the Field July 1989 1° x 1° File

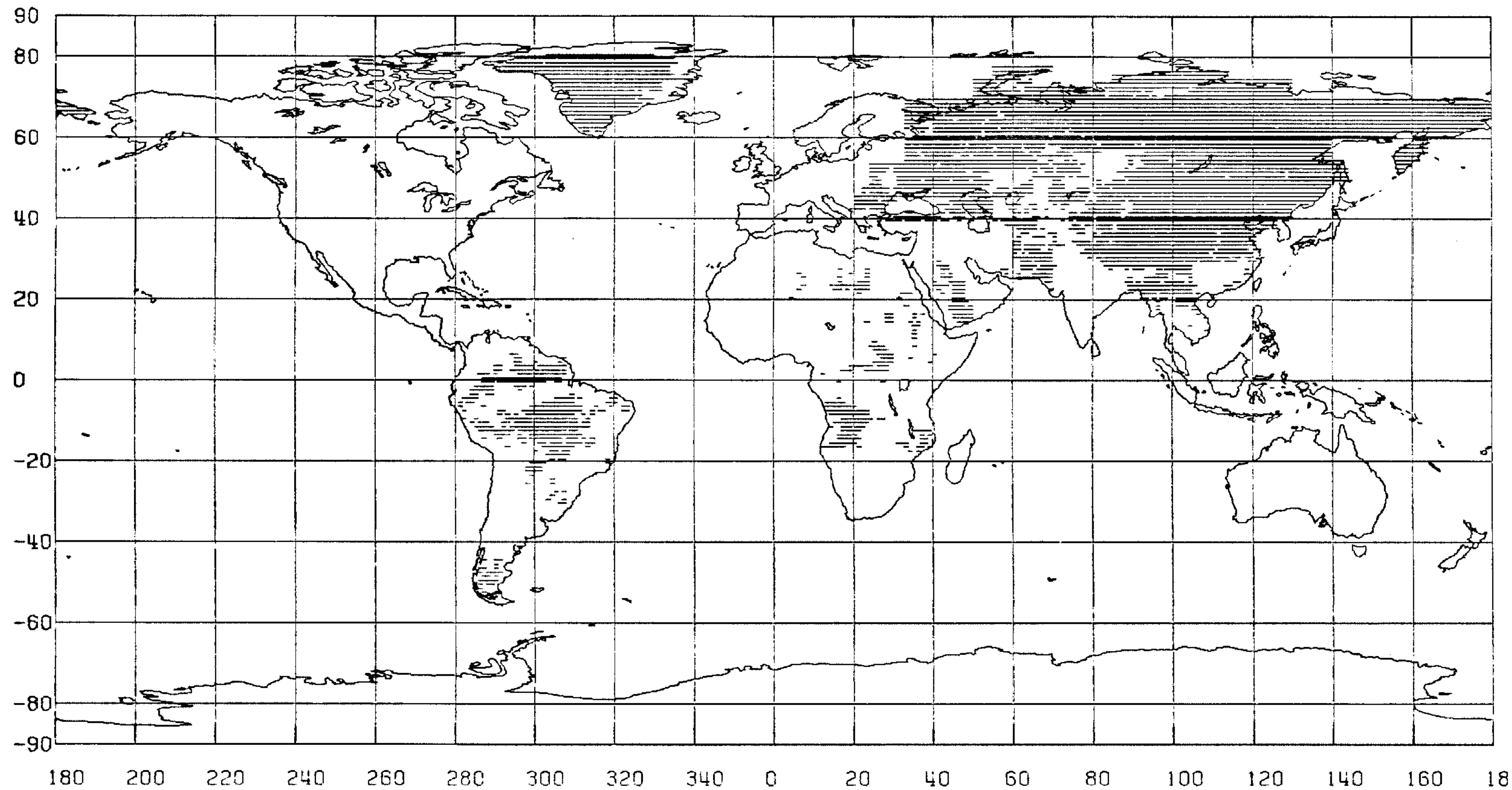

Figure 29. Location of 5667 Geophysically Predicted Anomalies in the July 1989 1° x 1° File

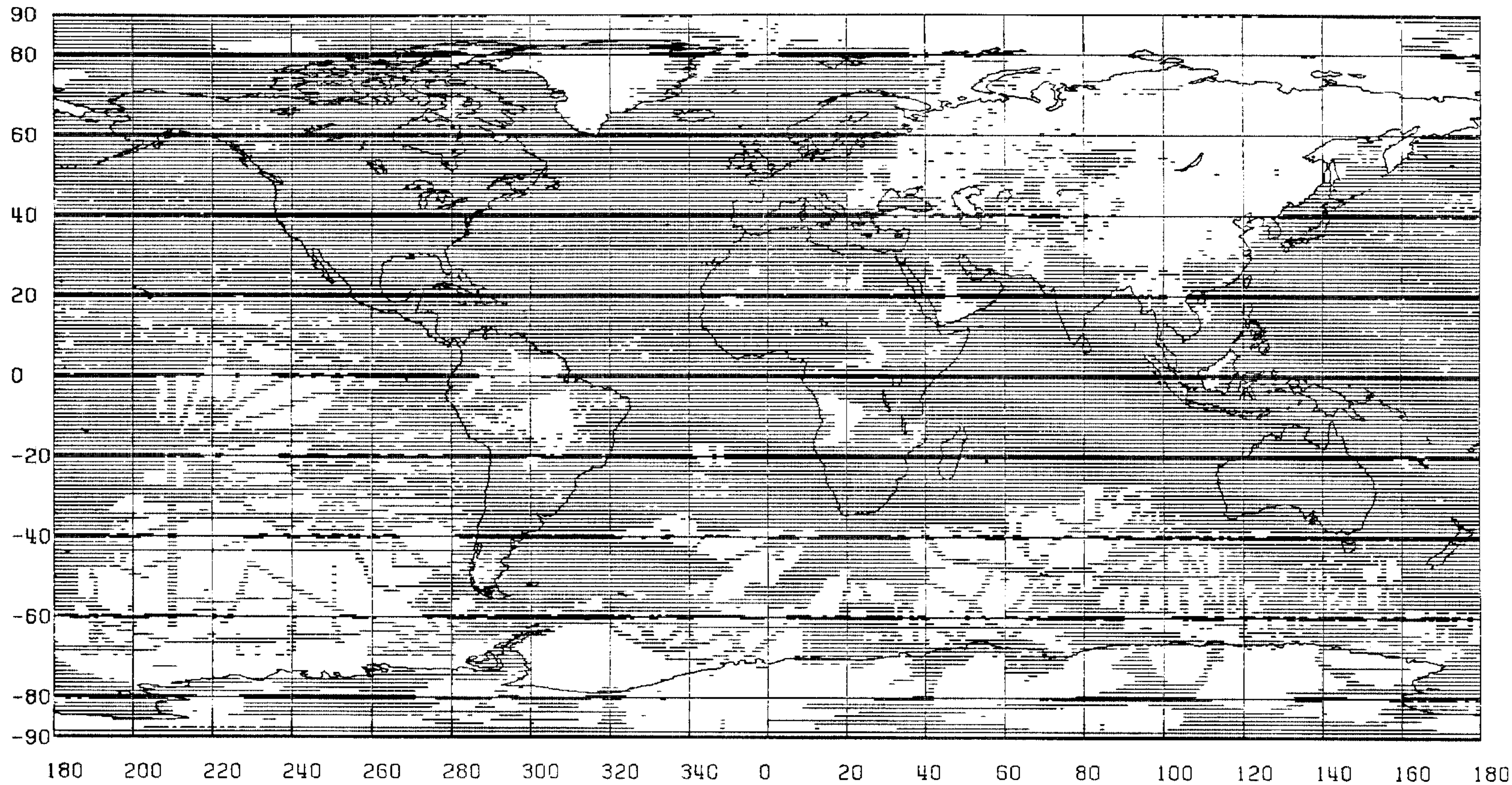

Figure 30. Location of 45126 Anomalies in the July 1989 1° x 1° File Excluding Geophysically Predicted Values

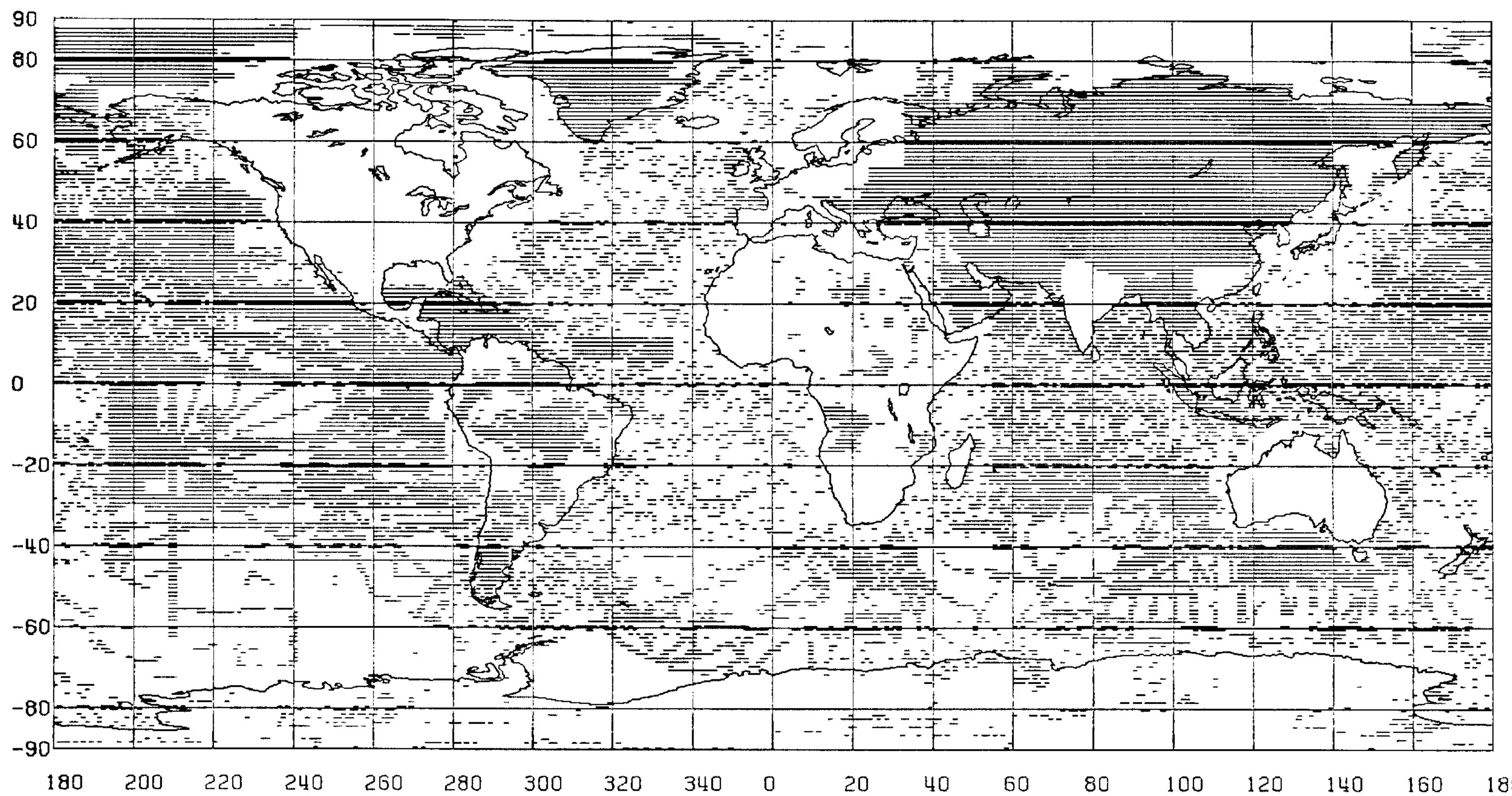

Figure 31. Location of the 23515 Anomalies from DMAAC in the July 1989 1° x 1° Field

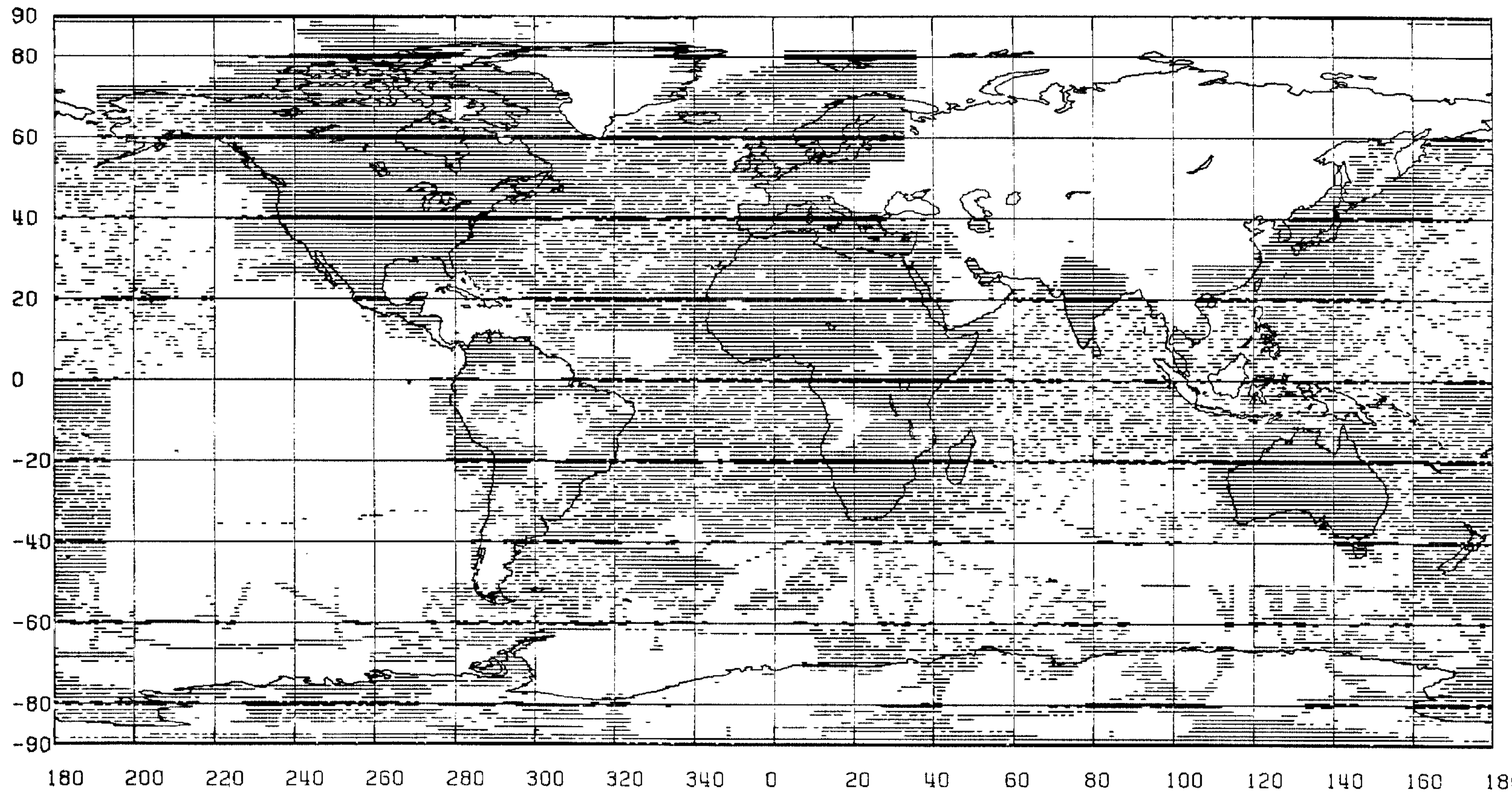

Figure 32. Location of the 27278 Anomalies in the July 1989 1° x 1° Whose Source is Not DMAAC

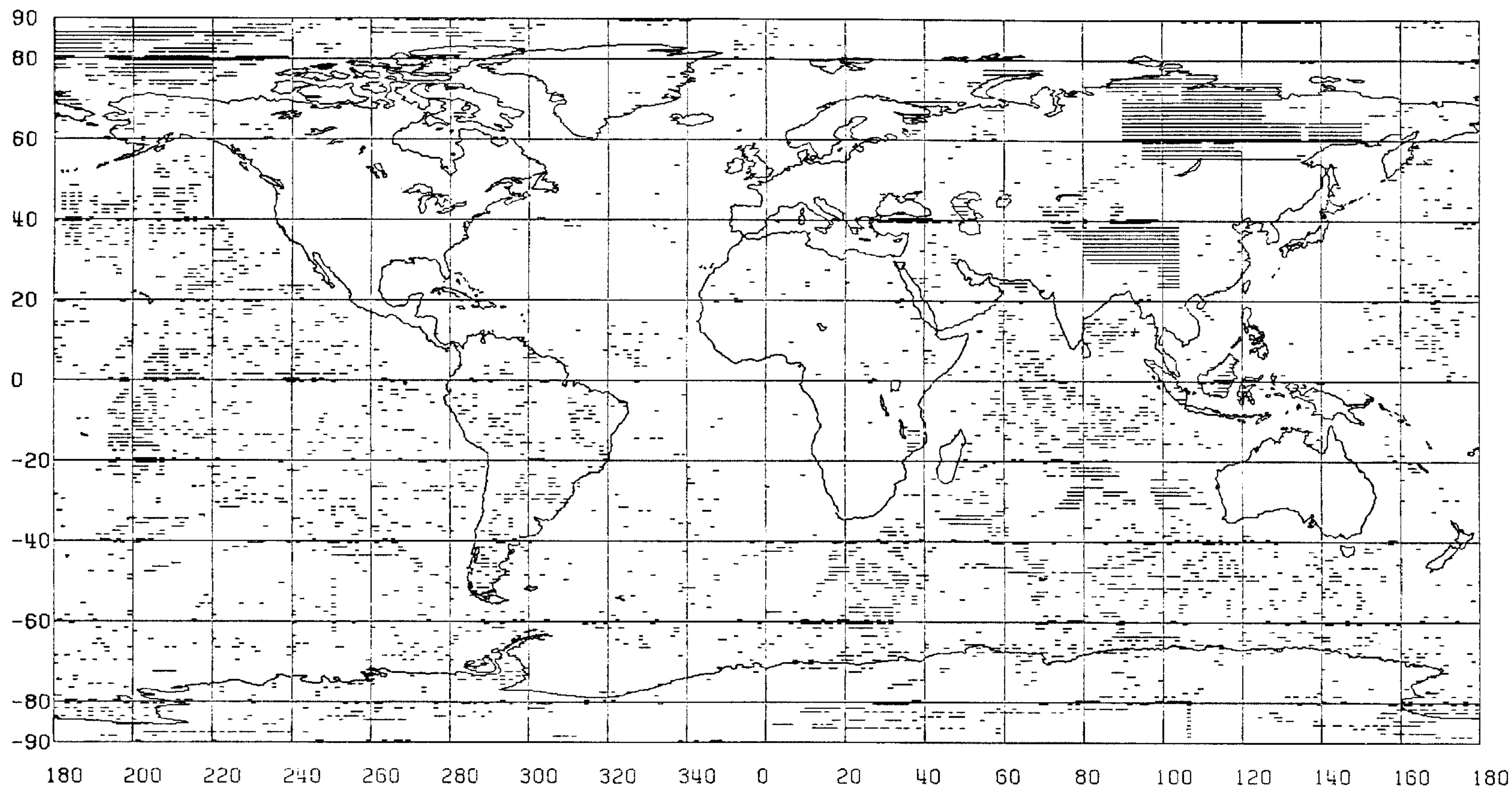

Figure 33. Location of 5837 Anomalies in the July 1989 1° x 1° Field With Standard Deviation ≥20 mgal

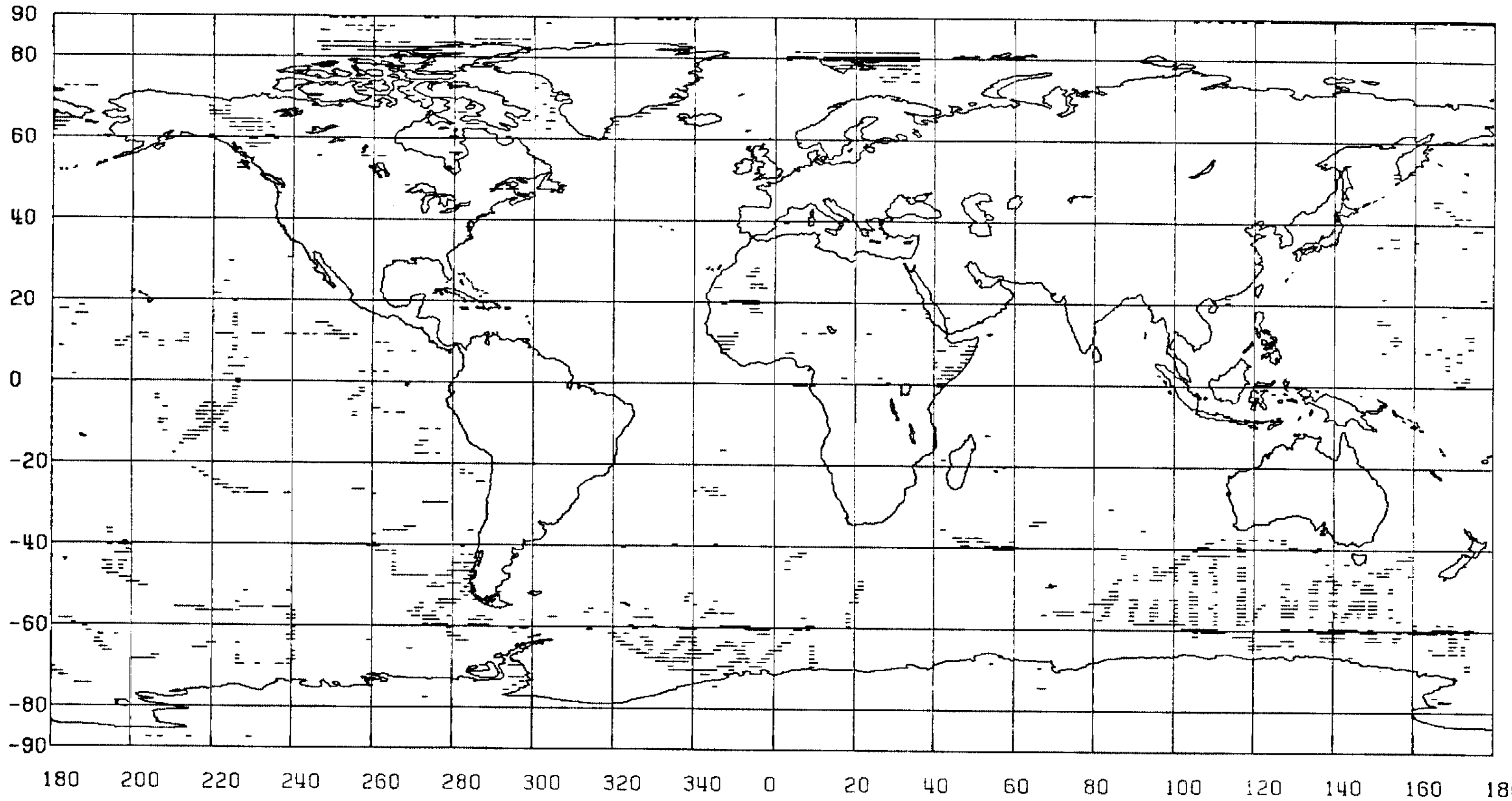

Figure 34. Location of 1838 1° x 1° Anomalies Available in the July 1989 Which Were Not Available in the June 1986 1° x 1° Field

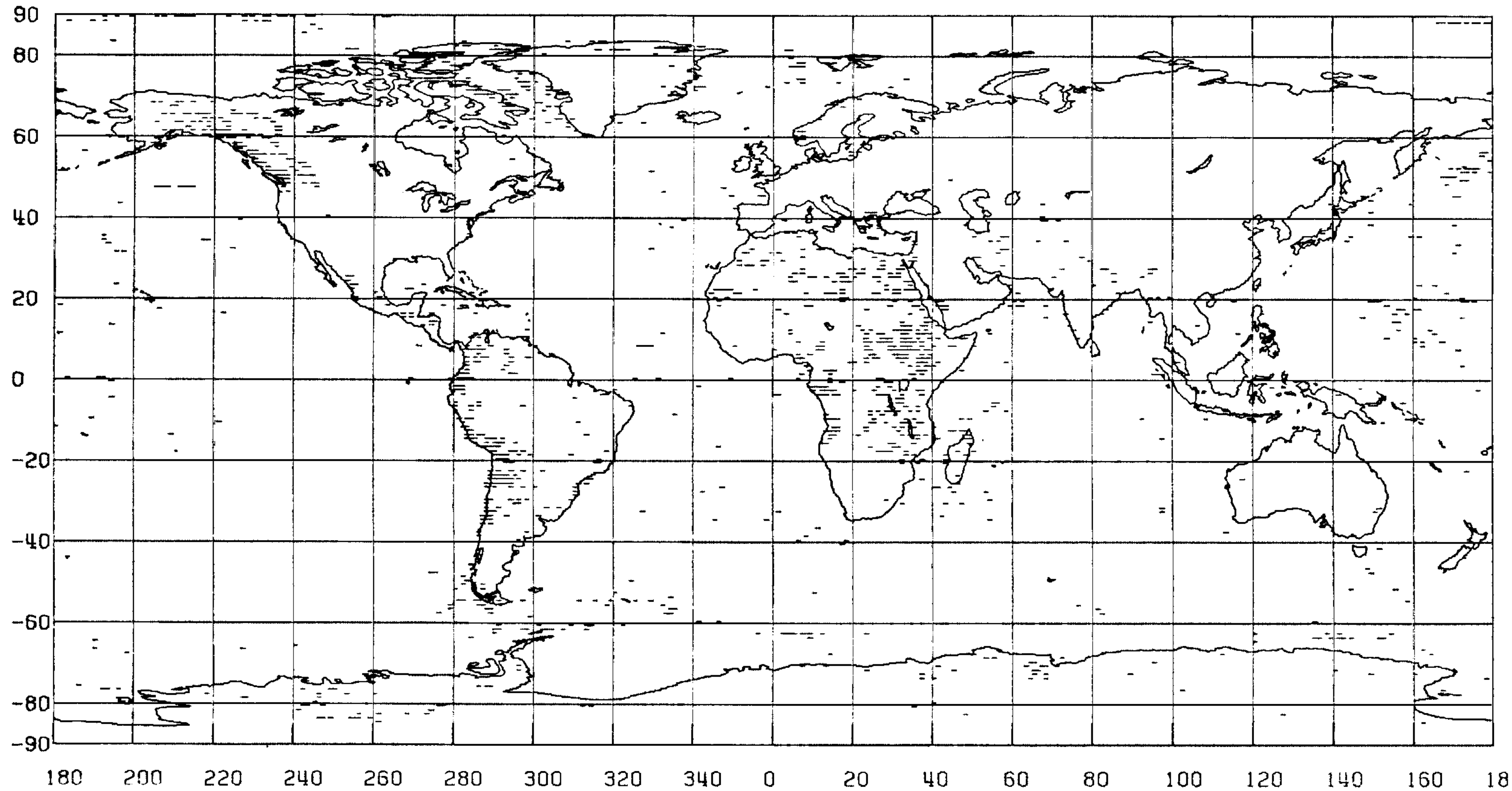

Figure 35. Location of 1478 1° x 1° Anomalies Where the Difference (June 1986 vs July 1989) Is ≥ 20 mgal

Table 9. Statistical Information for the JULY 1989 and the JUNE 1986 1° x 1° Field (in mgal)

	Northern Hemisphere		Southern Hemisphere		Global	
	JULY 1989	JUN 1986	JULY 1989	JUN 1986	JULY 1989	JUN 1986
No. of anomalies	28740	28005	22053	20950	50793	48955
Mean value	-0.5	-1.2	-0.6	-1.6	-0.5	-1.4
RMS value	27.8	28.1	26.6	26.7	27.3	27.5
Min value	-270	-271	-222	-223	-270	-271
Max value	303	339	200	191	303	339
Weighted mean	-1.4	-2.0	0.5	-0.6	-0.5	-1.3
Weighted RMS	28.2	28.6	26.1	26.1	27.3	27.5
Min σ	1.0	1.0	1.0	1.0	1.0	1.0
Max σ	57.0	62.0	47.0	47.0	57.0	62.0
RMS σ	12.8	14.0	14.4	14.6	13.5	14.2

Table 10. Statistics of (JULY 1989 1° - JUNE 1986 1°) (in mgal)

	Northern Hemisphere	Southern Hemisphere	Global
No. of common blocks	28005	20950	48955
Mean difference	0.5	1.0	0.7
RMS difference	8.3	7.5	8.0
Max difference	215	202	215
Min difference	-143	-109	-143

Table 11. Examples of Large 1° Anomaly Discrepancies Between the June 86 and the July 1989 1°x1° Data Files

ϕ (°)	λ (°)	Old Value in mgal (Source code)	New Value in mgal (Source code)	Difference in mgal (Old-New)
61	218	113 (1)	-30 (1019)	143
57	230	125 (54)	-13 (1036)	139
46	171	85 (44)	-37 (96)	122
27	94	-254 (1)	-39 (95)	-215
10	167	89 (1)	-36 (96)	125
-15	290	-76 (1)	126 (1038)	-202
-15	291	-26 (1)	165 (1038)	-191

Table 12
Number of Anomalies by Sources in the July 1989 1° Update

Source	Number of Anomalies
1	3574
2	3
5	4
6	1
20	5
23	1
27	1
28	10
29	18
31	7
32	10
34	3
35	20
36	6
37	11
38	8
43	45
44	533
45	116
46	292
47	1
48	97
49	1271
50	51
51	147
52	11
53	3
55	2052
56	120
57	431
60	1
63	37
64	285
67	2
71	8
72	1
78	446
79	1182
80	771
81	1065
85	60
86	6
87	3
90	4
95	3
96	19941
1001	334
1002	277
1003	1124

1004	959
1005	171
1006	519
1007	216
1008	222
1009	34
1011	1000
1013	32
1014	41
1016	107
1017	6
1018	43
1019	357
1020	8
1021	188
1022	851
1023	5
1024	46
1025	10
1026	2520
1027	13
1028	27
1029	3935
1030	102
1031	7
1032	6
1033	22
1034	82
1035	25
1036	3315
1037	237
1038	1285
Total	50793

6. Summary

The development of the July 1989 1° x 1° and 30′ x 30′ anomaly data sets is described in this report. The new data sets represent an update from our 1986 data sets. The actual incorporation of data in the new update is a task complicated by different estimates of anomaly values and accuracy estimates that are computed in different ways or are not given at all.

In our 1989 work we first developed an updated 30′ data file. Our emphasis in this development is on data from land areas since much of the ocean areas is covered by satellite altimeter data from which gravity anomalies can be derived. The first version of the 30′ file was used to estimate 1° x 1° anomalies which were then compared to an updated 1° x 1° file. Discrepancies revealed incorrect 30′ anomalies which were deleted from the 30′ file leading to the final July 89 30′ file containing 66990 anomalies and their accuracy. This number represents a doubling of the values obtained in the 1986 30′ update.

The 1° x 1° update was formed by merging our June 1986 file, a recent DMAAC file, and 1° x 1° anomalies computed from the final 30′ x 30′ data. Numerous criteria were applied to select the best anomaly estimates and their accuracy. The total number of anomalies (including 5667 geophysically predicted) is 50793 which represents an increase of 1838 from the June 1986 1° file.

The new anomaly fields represent not only an increase in the number of anomalies, but an increase in the quality of the data. The region with most significant quality improvement is Africa. The anomalies of past updates have been of poor quality in this region (Pavlis, 1988). However the new values, obtained through the efforts of the African Gravity Project, have greater coverage and greater accuracy.

The anomalies in the United States and Canada have been improved through the incorporation of gridded data files. These 4 km x 4 km or similar grids were averaged to form improved 30′ estimates. In doing this, we were able to improve values recognizing errors in some of the gridded data files.

Anomaly data in Central and South America was also acquired for this update. In some areas the point data is dense leading to well determined 30′ anomalies. In other areas the less dense data will have led to poorer anomaly estimates.

The development of these new files is due to the excellent cooperation of many organizations and individuals in providing data. Unfortunately numerous land areas lack data as is apparent by considering Figure 25 for 30′ x 30′ data and Figure 30 for 1° x 1° data. Hopefully the next update of these anomaly files will be able to include data from the areas in which the data is now lacking.

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Appendix A

LIST OF ANOMALY SOURCES CONSIDERED IN THE DEVELOPMENT OF THE AUGUST 1989 OSU 1° X 1° AND 30′ X 30′ ANOMALY DATA BASES

There are two sets of anomaly source lists. The first set is OSU's traditional 1° source list which has been used since 1972. The source code starts from 001 and 96 sources are listed for the 1989 update. The second set is the list of sources used for 30′ anomaly fields. It was used in the August 1986 creation of 30′ field for the first time, where the source code was from 001 to 010. There was a correspondence between 1° and 30′ source codes (Despotakis, 1986). As we now have new sources which are used for 30′ mean anomaly calculations, it was necessary to distinguish 30′ sources from 1° sources. For this new update, we number all the 30′ sources starting from 1001 which corresponds to source 001 in the 1986 30′ field. Note that 1° values from averaging 30′ values also carry the source code of 30′ majority source used in forming the 1° mean value. For further information on the 30′ sources, consult Despotakis (1986) and Chapter 3 of this report.

$1° \times 1°$ ANOMALY SOURCE CODE LIST

XXX: Code for source of anomaly information

No. 001	ACIC (now DMAAC) $1° \times 1°$ Mean Gravity Anomalies. Data obtained on tape U2380 from ACIC December 28, 1971. See ACIC format description. Next update May 1975. June 1976. Format changed in 1975. New tape January 1978, 1979, 1982, 1986.
No. 002	Ron Mather: $1° \times 1°$ mean free-air anomalies on IBM cards held at the School of Surveying, University of New South Wales. See letter dated November 24, 1971.
No. 003	University of Cambridge Free-Air Gravity Anomalies, Area 43, Two maps, point values and 25 mgal contour map. Contour map was used to estimate $1° \times 1°$ free-air anomalies, Date 04, 1970.
No. 004	Samir F. Vincent and William E. Strange Gravity Correlation Studies for Determination of Gravity Field of Earth. January, 1970. $1° \times 1°$ free-air anomalies were computed using elevation and mean $1° \times 1°$ Bouguer Anomaly information given on pp. 3-7 to 3-12.
No. 005	G.L. Strang Van Hees Gravity Measurements on the Atlantic Navado III. Report Luzern, 1967. Profile averages were used as $1° \times 1°$ mean free-air anomalies.
No. 006	University of Cambridge Free-Air Gravity Anomalies, Area 29, Two maps, point values and 25 mgal contour map. Contour map was used to estimate $1° \times 1°$ free-air anomalies. Date 10/29/69.
No. 007	Gravity Map of the Coral Sea and Solomon Sea. Contour interval 50 mgal with $\pm$ 20 mgal additions. See map for references.
No. 008	Ron Mather (Document 2665)
No. 009	Manik Talwani Indian Ocean Free-Air Anomaly Measured Values Averaged over $1°$ squares. See letter dated June 10, 1971.
No. 010	W.E. Strange and G.P. Woollard The Prediction of Gravity in the United States Utilizing Geologic and Geophysical Parameters. Final Report, Part II, November, 1964. Hawaii Institute of Geophysics, University of Hawaii. $1° \times 1°$ free-air anomalies used as given on Table 1, pp. 1-44.

No. 011 Bureau Gravimetrique Internationale Cartes Mondiales Anomalies de Bouguer. Laghauat-Rabot, 1969-1970. Bouguer anomaly contour map of Laghauat (10 mgal contour lines) and OSU 1° x 1° mean elevations were used to compute 1°x1° free-air anomalies.

No. 012 Bureau Gravimetrique Internationale Cartes Mondiales Anomalies de Bouguer Laghauat-Rabot, 1969-1970. Bouguer anomaly contour map of Rabot (10 mgal contour lines) and OSU 1° x 1° mean elevations were used to compute 1°x1° free-air anomalies.

No. 013 G.P. Woollard, L. Machesky, and J. Monges Cadera
A Regional Gravity Survey of Northern Mexico and the Relation of Bouguer Anomalies to Regional Geology and Elevation in Mexico. Final Report Part I, July 15, 1969. Hawaii Institute of Geophysics. University of Hawaii. 1°x1° free-air anomalies were used as given in Table 4, pp. 44-50.

No. 014 G.P. Woollard, M. Manghnani, and S.P. Mathur.
Gravity Measurements in India. Final Report, Part II, August 1, 1969. Hawaii Institute of Geophysics, University of Hawaii, 1°x1° free-air anomalies were used as given in Table 10, pp. 37-46.

No. 015 Richard J. Wold and Ned A. Ostenso
Gravity and Bathymetry Survey of the Artic and Its Geodetic Implications. JGR Vol. 76, No. 26, September 10, 1971. pp. 6253-6264. Free-air anomaly map with 10 mgal contour intervals were used to estimate 1°x1° anomalies.

No. 016 Mohammad Asadullah Khan and G.P. Woollard
Methods of Analysis and Comparison of Geophysical Data on a Plane, with Specific Application to the Solomon Islands Area. 1° x 1° mean free-air anomalies were used as given in Table A-3.

No. 017 Alaska Free-Air Anomaly Contour Map.
1° x 1° mean free-air anomalies were estimated using given map with 25 mgal contour intervals.

No. 018 William E. Strange
Carabea data containing 1° x 1° mean free-air anomalies.

No. 019 Carl Bowin
The Puerto Rico Trench Negative Gravity Anomaly Belt Contribution Number 2611 of the Woods Hole Oceanographic Institution. 1° x 1° mean free-air anomalies were estimated using 10 mgal contour interval map in Figure 3.

No. 020 P.A. Stroyev
Gravity Anomalies in the Sea of Japan JPRS 53962 September 1971. 1° x 1° mean free-air anomalies were estimated using 20 mgal contour interval map on page 3.

No. 021 John Woodside and Carl Bowin
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No. 022 Knopoffod Belshe
Gravity Observations of the Dead Sea Drift Region
Ref. 476, Institute of Geophysics, UCLA. 1° x 1° mean free-air anomalies were computed using 25 mgal contour interval Bouquer anomaly map, Figure 3, p. 12, and OSU 1° x 1° mean elevation data.

No. 023 J.G. Tanner
Canadian 1° x 1° free-air anomaly data obtained by computing average Bouguer anomalies using point value data and ACIC mean elevations, given either on 1°x1° cards or on 1° x 1° free-air anomaly tape.

If none of these (ACIC elevations) were given the positive average Canadian station elevation was used instead. If 1° x 1° mean elevation was less than 0, average free-air anomaly was used. See letter by J.G. Tanner, January 28, 1972.

No. 024 Not used.

No. 025 M. Bacon, F. Gray
A Gravity Survey, Earth and Planetary Survey Letters,
Vol. 10, No. 1, December 1970, p. 102. 1° x 1° mean free-air anomalies were read using 25 mgal contour line map.

No. 026 Free-Air Anomaly Maps on the Reykjanes Ridge and on the Iceland-Faeroe Ridge. Marine Geophysical Researches, Vol 1, No. 3, September 1971, p. 321, p. 323. Existing 20 mgal contour line free-air anomaly maps were used to estimate 1° x 1° free-air anomalies.

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Gravity Measurements at Sea by Use of the T.S.S.G. Part II, Results of the Measurements, Journal of Physics of the Earth, Vol 18, Nos. 3 and 4, 1970. 1° x 1° free-air anomaly data on 153 IBM cards from CSC in March 1972.

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Gravity Observations in Greenland. Data obtained on tape, September, 1973.

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Die Freiluftanomalien im Europäischen Bereich, Veröffentlichungen des Geodätischen Instituts in Potsdam. Nr. 25, 1964. Mean Free-Air Anomaly Values in Different Size Blocks.

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Mean Free-Air Anomaly Map with Contour Interval as 25 mgals in the paper: Geophysical Investigation of the Macquane Ridge Complex, published in The Antarctic Research Series Vol. 19 "Antarctic Oceanology II: The Australian New Zealnad Sector", pp. 211-234, Am. Geophys. Un. 1972.

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Gravity and Magnetic Investigations in the Guiana Basin, Western Equatorial Atlantic, Geological Soc. Amer. Bull. V. 84, pp. 3249-3268, 1973.

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Geophysical Anomalies and Tectonics in the Western Mediterranean, Bolletino Di Geofisica, Vol. XVIII, 67, pp. 211-249, September 1975.

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Gravity and Bathymetry in the Central Pacific Ocean, J. of Geophysical Research, Vol. 81, p. 1533, March 10, 1976.

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Gravimetric Geoid in the Northwest Pacific Ocean, Geophysical Journal of the Royal Astronomical Society, Vol. 50, No. 2, 1977.

No. 045 Watts, A., Gravity Field of the Northwest Pacific Ocean Basin and Its Margin: Philippine Sea, Geological Society of America, Map and Chart Series MC-12, Boulder, Colorado, 1975.

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Surveys and Mapping Branch, Department of Energy and Mines Resources, Ottawa, Canada. (Data given on tape received through letters dated January 12, 1979 and February 26, 1979 from G. Lachapelle).

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Free air gravity anomalies, Contour Interval 20 mgal, Prepared and Edited by N.P. Grushinky and M.B. Sazhina. (Map No. H-69/1-IV-78-A, H-70/1-IV-78-A, H-71/1-IV-78-A, H-72/1-IV-78-A.) Published by Ministry of Geology of the U.S.S.R.

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No. 058	Chad Magnetic Tape Containing Gravity Records received from DMAAC, St. Louis, Missouri, ref. letter dated August 25, 1978.
No. 059	Madagascar Free-air gravity anomaly chart giving anomalies for 1/4° x 1/4° for Madagascar area. (Anomalies chart brought by Prof. R.H. Rapp from I.B.G., Paris, June 1979)
No. 060	J.K. Weissel and A.B. Watts Paper entitled "Tectonic Evolution of the Coral Sea Basin". Journal of Geophysical Research, Vol. 84, No. B-9, August 10, 1979.
No. 061	Venezuela Free-air Gravity Anomaly Map entitled "Carta Gravimetrica", Republic of Venezuela, Contour Interval 20 mgal (received through letter dated June 7, 1979 from Dr. H. Drewes). (Not used)
No. 062	Kenya A Catalogue of Gravity Measurements, by C.J. Swain and M. Aftabkahn, Department of Geology, Leicester University, Leicester, England, July 1977.
No. 063	Maps from "Marin Geodesy" by Peter Dehlinger, Elsevier Scientific Publishing Co. 1978. Fig. 8.23 Rivera fracture zone Fig. 8.30 Coast of Chile Fig. 8.28 Coast of Peru Fig. 8.24 Otozco fracture zone in Mexico Fig. 8.25 Tehuauterec Ridge in Mexico and Guatemala Fig. 8.27 Coast of Central America Fig. 8.36 Center and Eastern Mediterranean Sea Fig. 8.15 West Coast of Southern California Fig. 8.16 West Coast of Oregon
No. 064A	A.B. Watts Gravity map of South-western Pacific received January 1980.
No. 064B	A.B. Watts Gravity map of South Central Pacific received January 1980.
No. 065	Wolfgang Torge, Georg Weber, Hans-Georg Wenzel "Determination of 12'x20' Mean free-air gravity anomalies for the North Sea Region", Report 247, Series B, German Geodetic Commission, Munich 1980.
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No. 067	"Contribuciones a la geodesia aplicada" Report made by the department of engineering of the University of Buenos Aires and presented in the XVII General Assembly of Geodesy and Geophysics in Australia December 1979.

No. 068 Defense Mapping Agency
New updated version in the Alaska area. Letter received in August 28, 1981.

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No. 071 Soviet maps: "Gravity map of Australia, Indonesia and Surrounding seas and oceans" on 10 sheets, in two versions - free-air and Bouguer anomalies, by N.P. Grushinsky and N.B. Sazhina (1978), Academy of Sciences of the USSR, Soviet Geophysical Committee, World Data Centre B2. Sent by V.N. Badkovsky, Chief Solid Earth Group. Values estimated for blocks missing from the July 1981 (1° x 1°) - tape.

No. 072 surrounding Australia; values estimated from Soviet maps (see No. 071). overlapping source 1.

No. 073 Bene Through, Nigeria, By Col. Adighije, a paper "A Gravity Interpretation of the Bene Through Nigeria" from Tectonophysics, Vol. 79, 1981, pp. 109-128.

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No. 075 North Sea gravity anomaly data. Dutch tape GS184 from G. Strang van Hees, July 2, 1981. Geodetic Institute, Delf University of Technology, Netherlands.

No. 076 "10' x 10' Detailed Gravimetric Geoid Around Japan" by Yasuhiro Ganeko, Hydrographic Department of Japan on tape (GS 246) sent on data set is also described in the paper - title and author above - presented on General Meeting of IAG, Tokyo, May 1982.

No. 077 a single value for (-32°, 18°) block estimated from Bouguer map published in "Gravity Survey of Degree Square 3218" by H. van Gysen and C.L. Merry in Technical Report TR-1 August 1982, University of Cape Town, Department of Surveying.

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No. 079 E. Magnitskaya, J. Cochran, M. Kogan, and A. Watts
Soviet Maps, Free-Air Gravity Field of the South Atlantic Ocean in six sheets, published by the Head Department of Navigation and Oceanography, USSR, Ministry of Defense, by the order of Institute of Physics of the Earth, USSR Academy of Sciences (printed in 1983).

No. 080 A.B. Watts, M.G. Kogan, J. Mutters, G.D. Kamer, and F.J. Davey. Free-Air Gravity Field of the Southwest Pacific Ocean in 2 Charts, published by the Geological Society of America, Map and Chart Series MC-42 (1981).

No. 081 Woo-Yeol Jung (Texas A&M University). 1° x 1° Tabulated Mean Free-Air Gravity Anomalies of the North Atlantic Ocean. Letter dated June 18, 1985.

No. 082 J. Albouy and R. Godivier. Maps of the Central African Republic. Bouguer Gravity Anomalies in 3 Sheets, published by the Office de la Recherche Scientifique et Technique outre-mer, Paris, France 1981.

No. 083 Bouguer Gravity Map of Zimbabwe published in F. Podmore: The Progress of Gravity Survey in Zimbabwe, first edition, September 1981.

No. 084 Free-Air Anomaly Map of Portugal in 4 Sheets (1 Free-Air, 1 Bouguer, 1 Complete Bouguer, 1 Isostatic) by A. Torres (1983).

No. 085 W. Torge et al. 6' x 10' Mean Free-Air Dg in Europe, in Tape EUROP sent to us by the Institut für Erdmessung, Hannover (letter dated 8/12/1983).

No. 086 Tape BLITZ sent to us by DMAAC with point gravity data in Brazil by Denizar Blitzkow, letter dated 11/23/83.

No. 087 Free-Air on Sea-Bouguer on Land Map of West Canada by Earth Physics Branch Energy, Mines and Resources, Canada 1982, letter dated 11/1/84.

No. 088 J. Segawa, T. Matsumoto, and K. Kaminuma. Free-Air Gravity Anomaly of the Antarctic Region, Special Map Series of National Institute of Polar Research, 1984.

No. 089 1° x 1° Gravity Data in Greenland on Tape CCTAP, file 17, by Rene Forsberg (letter dated 12/23/85).

No. 090 A free-air anomaly map found on page 92 of the article: Gravity Field Analysis of SIO-GUYOT: An Isostaticlally Compensated Seamount in the Mid-Pacific Mountains, in GEO-MARINE Letters Journal, Vol. 5, 1985, No. 2, pp. 91-97.

No. 091 Tape AUSTRA with point gravity data in Australia received in July 1985.

No. 092 1° x 1° Mean Free-Air Gravity Anomalies in India, by R.K. Verma (Indian School of Mines, Dhanbad) obtained from the Bouguer and Free-Air Anomaly Map, published by the National Geophysical Research Institute, letter dated 1/23/84.

No. 093 Tape UCT1, file 2, 1° x 1° mean free-air gravity anomalies is S. Africa, by C.L. Merry (letter dated 2/28/86).

No. 094 A.B. Watts, G.D. Karner, P. Wessel, and J. Hastings: Global Gravity Data Bank System, Lamont-Doherty Geological Observatory of Columbia University, September 1985, Palisades, NY 10964.

No. 095 Three Empirical Values for the Three 1° x 1° Block in Asam, India, by R.H. Rapp.

No. 096 DMAAC
$1^\circ \times 1^\circ$ Mean Anomalies in Tape SL059 sent by S.D. Icenhower, See letter dated May 5, 1989.

30' x 30' ANOMALY SOURCE CODE LIST

No. 1001 C.L. Merry
Tape UCT1, file 1 contains 30' x 30' mean anomaly in South Africa. Corresponding to 1° source 93

No. 1002 A. Mainville
Tape E14273, file 2, Gravity data in Canada and U.S., Received July 1984 Corresponding to 1° source 54

No. 1003 Corresponding to 1° source 91

No. 1004 Corresponding to 1° source 85

No. 1005 Corresponding to 1° source 86

No. 1006 Corresponding to 1° source 76

No. 1007 Corresponding to 1° source 89

No. 1008 R.K. Verma, 846, 30' x 30' anomalies in India in tabulated form. Corresponding to 1° source 92

No. 1009 Corresponding to 1° source 78

No. 1010 Corresponding to 1° source 48

No. 1011 4 km x 4 km gridded data by Rapp and Zhao (1988)
Stored in file 2 of GS383. Originally based on the 4 km x 4 km gridded data by the Society of Exploration Geophysicists in 1982.

No. 1012 M. Zuber
Tape AGRAV2, file 2, letter dated 12/18/87. 10 km x 10 km grid of Bouguer anomalies in Australia.

No. 1013 S.D. Icanhower
Tape SL045, letter dated 05/10/88. Point free-air anomalies in Brazil, based on data originally provided by D. Blitzkow.

No. 1014 P. Kletsas
Tape S001, letter dated 05/18/88. $5' \times 6'.25$ mean free-air anomalies in Greece.

No. 1015 Barringer Geoservices
An IBM floppy disk. 30' mean free-air anomalies and Bouguer anomaly in Zambia.

No. 1016 G. Balmino
Tape JALES2, letter dated 10/03/86. $0^\circ.25 \times 0^\circ.25$ mean free-air anomalies in Madagascar and surrounding areas.

No. 1017 K. Omar

The Prediction of Point Free-air Gravity Anomalies for North Western Peninsulas Malysia, Technical paper, Dept. of Geodetic Science and Surveying, The Ohio State University, Columbus, 1988.

No. 1018 A.B. Watts
Tapes WATTSS1, WATTSS2, letter dated 04/16/87. Point free-air anomaly in the Hawaiian Island.

National Geodetic Surveying (NGS)
Point free-air and Bouguer anomalies in the Hawaiian Island. Received in 1983 and stored in Tape GS202.

No. 1019 NGS
Received in 1983 and stored on tape GS202. Point free-air anomalies in Alaska.

No. 1020 NGS
Received in 1983 and stored on tape GS202. Point free-air anomalies in Bermuda.

No. 1021 A. Mainville
Tapes GDC142 and GDC143, letter dated 06/29/88. Point free-air anomalies in Canada.

No. 1022 D. Sölheim
Tapes MTRHRO and MTRHRN, letters dated 11/18/88 and 01/13/89. 30′ mean free-air anomalies in Scandinavian area.

No. 1023 R. Chang
A 10′ x 10′ mean free-air anomaly map in Taiwan received in October 1988.

C. Lin
A free-air anomaly map of Taiwan, February 1989.

No. 1024 A.S. Lwangasi
30′ mean free-air anomalies in Kenya, in 4 maps with tabulated values, letter dated 11/14/88.

No. 1025 J. Renner
Final Elaboration of the Measurements of the National Hungarian Network of Gravity Bases, Geofizikai Közlemeryek, Vol. III, 3, pp. 105-141, 1959. Made available by J. Adam in a floppy disket.

No. 1026 National Geophysical Data Center in Boulder
purchased tape W02761, sent on 9/14/88. Point free-air anomalies in Antarctica.

No. 1027 K. Choi
Point free-air and Bouguer anomalies in a floppy disk, and 30′ mean free-air anomalies in a tabulated map, available in 1989.

No. 1028 H.I. Götze, S. Schmidt, S. Strunk
Central Andean Gravity Field and its Relation to Crustal Structure, in The Southern Central Andes, H. Bahlburg, C. Breitkenz, P. Giese (eds.), Lecture

Notes in Earth Science, Vol. 17, Springer Verlag, Berlin, 1988. A free-air anomaly map sent by M. Beck, letter dated 09/16/87.

No. 1029 Africa Gravity Project
Tape F37699, sent by C. Green, letter dated 03/02/89. 30′ mean free-air anomalies in Africa area and surrounding seas.

No. 1030 J. Segawa
Tape JAPAN, letter dated 03/20/89. 5′ x 5′ mean free-air anomalies in Japan and surrounding seas.

No. 1031 The Bouguer anomaly map of Sri Lanka from The National Atlas of Sri Lanka by the Survey Department of Sri Lanka. Available by Somasekarm (1988).

No. 1032 D. Arabelos
Tape XYT433, letter dated 05/10/89. 6′ x 10′ and 30′ x 30′ mean anomalies in the Eastern Mediterranean.

No. 1033 C. Aiken
Tape AIKGR1, file 1, letter dated 05/11/89. Point Bouguer and free-air anomalies in Central America.

No. 1034 C. Aiken
Tape AIKGR1, file 2, letter dated 05/11/89. Point Bouguer and free-air anomalies in the Texas area.

No. 1035 S. Gerrard
Received through BITNET on 06/16/89 and 06/23/89. 30′ mean free-air anomalies in England.

No. 1036 D.B. Hearty, Geological Survey of Canada, Ottawa, Ontario
Tape GDC126, letter dated 02/18/88. 5 km x 5 km gridded free-air anomalies in Canada and the Northern part of USA.

No. 1037 C. Aiken
Tape AIKGR1, file 3, letter dated 05/11/89. Point Bouguer and free-air anomalies in the Mexico area.

No. 1038 C. Aiken
Tape AIKGR1, file 4, letter dated 05/11/89. Point Bouguer and free-air anomalies in the South America.

Appendix B

FORMATS AND DESCRIPTION OF FILES ON TAPE GS322 (1° FIELD) AND ON TAPE GS327 (30′ FIELD)

1. OSU Format for 1° x 1° Anomaly Data

Each file on tape GS322 contains 180 records for 180 1° latitude belts from north to south, starting from 90° and ending at -89°. Each record contains information for 360 1° blocks in a latitude belt from west to east, starting from 0 (the Greenwich meridian) and ending at 359. A 1° x 1° block is identified by the latitude and longitude of its northwest corner.

The first piece of information of each record is the identification of the latitude belt and the rest is composed of 360 sets of information for 360 1° x 1° blocks. Each set contains 13 items of information on each 1° x 1° block. Thus, in each record, there are 4681 pieces of information (1+300*13). The 13 items are now described.

1) Longitude of the 1° x 1° block in degrees (northwest corner)
2) Code for the method of evaluation of the free-air anomaly. For source 1 through 96 this code has 6 possible values, primarily for DMAAC sources (source 1 and 96).

Code	Method
1	Modified average
2	Free-air anomaly map estimates
5	Simple average from observations
9	Least Squares Estimation
15	Geophysical Correlation
16	Special - see reduction history for details

3) Free-air anomaly referred to the gravity formula of GRS67; in mgals
4) Standard deviation of free-air anomaly in mgals
5) Number of points or mean free-air anomalies used to estimate the free-air anomaly
6) Bouguer anomaly in mgals. (This is rarely given in our files.)
7) Standard deviation of Bouguer anomaly in mgal
8) Number of stations used to estimate the Bouguer anomaly
9) Number of 30′ blocks used for estimation or comparison
10) Mean elevation from TUG87 in meters
11) Accuracy code for elevation. (This is not applicable for these files.)
12) Source identification code. Code list is in Appendix A1.
13) Code for type of value where type is one of the following:
    1. Update of an existing value including the case of no change of the anomaly value.
    2. New anomaly, i.e., no value available before.

Note that items 6, 7, and 11 are obsolete as information on Bouguer anomalies is not given anymore. Item 11 is also obsolete as TUG87 elevation has no information on the accuracy. Values for these items are written as 9999. Note that if a free-air anomaly is derived from more than 1 30′ source the code of the most frequent source for items 2 and 12 are recorded.

All information is written on Tape GS322 unformatted in INTEGER * 2 bytes. Information on item 1 and 10 is always available. For the others if no information is available, 9999 is given for the value. A list and description of files on tape GS322 are shown in Table B1 and B2 respectively. A sample program to read tape GS322 is given in Table B3.

Table B1

List of 1° x 1° Files on Tape GS322

File No.	Data Set Name
1	JUN86
2	JUN86.TUG87
3	JUN86.TUG87.DMA87
4	JUN86.TUG87.DMA87.MER
5	AUG88.TEMP
6	AUG88.TEMP.COR
7	JUN86.MER.DMA89
8	ONEDEG.FROM.THIRTY
9	ONEDEG.FROM.THIRTY.JULY1389.ELEV
10	TERR.ONEDEG.TUG87.JULY1389
11	ONEDEG.MER3.NEW21.JULY2189
12	ONEDEG.MER79.NEW2.JULY2189
13	ONEDEG.FROM.THIRTY.JULY2189.ELEV
14	TERR.ONEDEG.TUG87.JULY2189

Table B2

Description of 1° x 1° Files in Tape GS322

File No.	Description	Remark
1	Original 1° file of '86 update	Despotakis '86
2	file 1 + TUG87 30′ elevation	Pavlis '88
3	file 2 + DMAAC87	Despotakis '88
4	file 3 + correct DMAAC codes for geophysically predicted anomalies	Despotakis '88
5	file 4 + New 1° sources	Despotakis '88
6	file 5 + correct code of evaluation and source for several DMAAC values	Despotakis '88
7	DMA89 + JUN86 (file 3) + Alt '85	Kim '89
8	1° from 30′ of file 17 GS327	Kim '89
9	1° from 30′ of file 18 GS327 after deleting problem block values and adding TUG87 elevation	Kim '89
10	file 9 + file 3 + code for 3 blocks (S59) and DMA code = 1	Kim '89
11	TS0040.JUN86.TUG87.DMAMOE87 + DMA89 with a new criterion to avoid choosing bad DMA89 values in sea areas + DMA89 Source ID set to 96	Kim '89
12	file 11 + file 8	Kim '89
13	1° from 30′ of file 19 GS327	Kim '89
14	file 13 + file 11	Kim '89

Table B3

Sample Program to Read Standard 1° x 1° OSU Format Tape

```
// JOB
/* SETUP UNIT=TAPE9, ID = (GS322, SLOT, READ)
// PROCLIB DD DISP=SHR, DISN=GEODSCI.PROCLIB
// EXEC VSSUPER
// GO.SOURCE DD *
       INTEGER*2 T (4681)
       DO 10 I=1, 180
       READ (1) T
       LAT=T (1)                       (Read latitude)
       DO 10 J=1,360
       J1=(J-1)*13+1
       LON=T(J1+)                      (Read longitude)
       ICE=T(J1+2)                     (Read code of evaluation)
       IFA=T(J1+3)                     (Read free-air anomaly)
       ISD=T(J1+4)                     (Read standard deviation)
       IST=T(J1+5)                     (Read number of station)
       NUMB=T(J1+9)                    (Read number of 30′ blocks)
       IELEV=T(J1+10)                  (Read TUG87 elevation)
       ISRC=T(J1+12)                   (Read code for source)
       ITYP=T(J1+13)                   (Read type of value)
   10  CONTINUE
       .
       .
       STOP
       END
// GO.FT01F001 DD DISP=(OLD, PASS), VOL=SER=GS322,
//     LABEL=(14, SL,, IN), DSN=TERR.ONEDEG.TUG87.JULY2189,
//     DCB=(RECFM=VBS, LRECL=9366, BLKSIZE=9370, DEN=4),
//     UNIT=TAPE9
```

2. OSU Format for 30′ Field

Each file on tape GS327 contains 360 records for 360 30′ latitude belts from north to south, starting from 90° and ending at -89°.5. Each record contains information for 720 30′ blocks in a latitude belt from west to east, starting from 0° (the Greenwich Meridian) and ending at 359°.5. A 30′ x 30′ block is identified by the latitude and longitude of its north-west corner.

Each record for a 30′ latitude belt is composed of 720 sets of information for 720 30′ x 30′ blocks in the latitude. Each set contains 7 pieces of information on each 30′ x 30′ block. Thus, in each record, there are 5040 pieces of information (7*720). The 7 pieces of information are as follows:

1) TUG87 elevation in meters
2) Number of point or mean free-air anomalies used to estimate free-air anomaly
3) Free-air anomaly * 10, referred to the Geodetic Reference System 1967, in mgals
4) Standard deviation of the free-air anomaly in mgals
5) Code for the method of evaluation of the free-air anomaly. This code has 4 possible values:

Code	Method
2	Simple average of point or mean anomalies
3	least square collocations
4	tabulated data
5	map estimation

6) Source identification code (see Appendix A for list)
7) Code for type of value
   1. Update of an existing value including case of no change in value.
   2. New anomaly. No value was available earlier.

All information is written on tape GS327 unformatted in INTEGER*2 bytes. If no information is available for certain items, 9999 is written on the corresponding items. A list and description of files on tape GS327 are shown in Table B4 and B5 respectively. A sample program to read tape GS327 is given in Table B6.

Note that ten times the free-air anomaly value is recorded in the item 3 to keep an accuracy of one decimal digit. Note that the latitude and longitude of the 30′ x 30′ blocks are not explicitly recorded.

Table B4

List of 30′ x 30′ Files on Tape GS327

File No.	Data Set Name
1	HALF.F1
2	HALF.AUG86
3	HALF.F3
4	HALF.AUG86.OR
5	HALF.AUG86.TUG87
6	HALF.JULY88
7	HALF.JULY88.TUG87
8	HALF.AUG88.OR.TEMP
9	HALF.AUG88.OR.TUG87.TEMP
10	HALF.AUG86.OR.ELEV.OSUJAN89
11	HALF.FEB89A.OR.ELEV.OSUJAN89
12	HALF.MAR89A.OR.ELEV.OSUJAN89
13	HALF.MAY89A.OR.ELEV.OSUJAN89
14	HALF.JUN89A.OR.ELEV.OSUJAN89
15	HALF.JUN89B.OR.ELEV.OSUJAN89
16	HALF.JUN89C.OR.ELEV.OSUJAN89
17	TEMP72.COR.JUL12
18	TERR.HALFDEG.TUG87.JULY1389
19	TERR.HALFDEG.TUG87.JULY2189

Table B5

Description of 30′ x 30′ Files in Tape GS327

Files No.	Description	Remark
1	Base for file 2	Despotakis '86
2	Modified 30′ x 30′ Δg data	Despotakis '86
3	Base for file 4	Despotakis '86
4	Original 30′ x 30′ Δg data	Despotakis '86
5	file 2 + file 2 of GS367 (DSN=TUG87M30.DTM)	Priovolis '88
6	file 5 + TS3862.USAMER TS3862.AUSMER TS3862.BRAMER	Priovolis '88
7	file 6 + file 2 of GS367 (DSN=TUG87M30.DTM)	Priovolis '88
8	file 4 + (SXXM, XX=11, 12,..., 21)	Despotakis '88
9	file 8 + file 2 of GS367 (DSN=TUG87M30.DTM)	Despotakis '88
10	file 4 + (TUG87 30′ elevation)	Pavlis '88
11	file 10 + (Source 1011 ~ 1021)	Kim '89
12	file 11 + (Source 1022 ~ 1025)	Kim '89
13	file 12 + (Source 1026 ~ 1031)	Kim '89
14	file 13 + (Source 1027, 1032, 1033, 1034, 1036)	Kim '89
15	file 14 + (Source 1035, 1037, 1038)	Kim '89
16	Adding 1000 to the source I.D. No.	Kim '89
17	Deleting 2 values of S1018 and changing 12 values of S1002	Kim '89
18	Deleting values of problem blocks in July 13 '89	Kim '89
19	Deleting values of problem blocks in July 21 '89	Kim '89

Table B6

Sample Program to Read Standard 30′ x 30′ OSU Format Tape

```
// JOB
/* SETUP UNIT=TAPE9, ID=(GS327, SLOT, READ)
// PROCLIB DD DISP=SHR, DSN=GEODSC1.PROCLIB
// EXEC VSSUPER
// GO.SOURCE DD *
        INTEGER*2  T (5040)
        DO 10 I=1,360
        READ (1) T
        XLAT=90.-0.5*(I-1)                (Compute latitude)
        DO 10 I=1, 720
        J1=(J-1)*7
        XLON=(J-1)*0.5                    (Compute longitude)
        IELEV=T(J1+1)                     (Read TUG87 elevation)
        NUMP=T(J1+2)                      (Read number of points or mean values)
        FA=T(J1+3)/10                     (Read free-air anomaly)
        ISD=T(J1+4)                       (Read standard deviation)
        IC=T(J1+5)                        (Read code for evaluation)
        IS=T(J1+6)                        (Read code for source)
```

```
      IT=T(J1+6)                          (Read code for type of value)
      .
      .
   10 CONTINUE
      STOP
      END
// GO.FT01F001 DD DISP=(OLD, PASS), VOL=SER=GS327,
//    LABEL=(19, SL,, IN), DSN=TERR.HALFDEG.TUG87.JULY2189,
//    DCB=(RECFM=VBS, LRECL=10084,BLKSIZE=10088, DEN=4),
//    UNIT=TAPE9
```

Appendix C

Transmittal Format of the July 1989 1° x 1° Field

For efficient storage and retrieval a modified format for the transmittal of the July 1989 1°x1° field was developed by Tsaoussi. The program used to create the modified tape is saved as TS4757.COPOU026. The listing of this program is given in Table C1. The listing of the program to read the tape is stored as TS4757.RIDOU026 and is shown in Table C2. The description of the information on the modified format tape follows Table C2.

Table C1
Sample Program to Create 1° x 1° OSU Modified Tape

```
// JOB ,
// REGION=4096K,TIME=(2,0)
/*JOBPARM LINES=2000,TAPEIO=19000,V=R
/*SETUP UNIT=TAPE9,ID=(GS322,SLOT,READ)
/*SETUP UNIT=TAPE9,ID=(OUXXX,SLOT,WRITE)
//PROCLIB DD DISP=SHR,DSN=GEODSCI.PROCLIB
// EXEC VSSUPER
//GO.SOURCE DD *
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C   TS4757.COPOU026                                          C
C   PROGRAM TO COPY JULY 1989 1 DEG FIELD (FILE#14,GS322)    C
C           ON A TAPE FOR OUTSIDE USERS                      C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      INTEGER*2 T89(4681),T(13),LAT
      NUM=0
      DO 10 I=1,180
      READ(1) T89
      LAT=T89(1)
      WRITE(10,1) LAT
    1 FORMAT(I3)
      NUM=NUM+1
      DO 20 J=1,360
      J1=(J-1)*13+1
      DO 30 L=1,13
      T(L)=T89(J1+L)
   30 CONTINUE
      WRITE(10,2) (T(L),L=1,4),T(10),T(12)
    2 FORMAT(I3,3I4,I6,I4)
      NUM=NUM+1
   20 CONTINUE
   10 CONTINUE
      WRITE(6,3) NUM
    3 FORMAT(//,5X,'NUMBER OF RECORDS IN THE FILE  :',I7)
  100 FORMAT(14I5)
      STOP
      END
//GO.FT01F001 DD DISP=(OLD,PASS),VOL=SER=GS322,
//  LABEL=(14,SL,,IN),DSN=TERR.ONEDEG.TUG87.JULY2189,
//  DCB=(RECFM=VBS,LRECL=9366,BLKSIZE=9370,DEN=4),
//  UNIT=TAPE9
//GO.FT10F001 DD UNIT=TAPE9,DISP=(NEW,PASS),LABEL=(1,BLP,,OUT),
//  DCB=(OPTCD=Q,RECFM=FB,LRECL=25,BLKSIZE=5000,DEN=4),
//  VOL=SER=OUXXX
/*
//
```

Table C2
Sample Program to Read 1° x 1° OSU Modfied Tape

```
// JOB ,
// REGION=4096K,TIME=(2,0)
/*JOBPARM LINES=2000,TAPEIO=19000,V=R
/*SETUP UNIT=TAPE9,ID=(OUXXX,SLOT,READ)
//PROCLIB DD DISP=SHR,DSN=GEODSCI.PROCLIB
// EXEC VSSUPER
//GO.SOURCE DD *
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C   TS4757.RIDOU026                                         C
C   PROGRAM TO READ JULY 1989 1 DEG FIELD (FILE#14,GS322)   C
C           WRITTEN ON A TAPE FOR OUTSIDE USERS ( OUXXX )   C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      INTEGER*2 T(6)
      DO 10 I=1,180
       READ(1,100) LAT
 100   FORMAT(I3)
        DO 10 J=1,360
        READ(1,200) T
 200    FORMAT(I3,3I4,I6,I4)
        LON=T(1)
        ICI=T(2)
        IFA=T(3)
        ISD=T(4)
        IELEV=T(5)
        ISRC=T(6)
       IF(LAT.NE.30) GO TO 10
       IF(LON.GT.20) GO TO 10
       WRITE(6,300) LAT,LON,ICI,IFA,ISD,IELEV,ISRC
 300   FORMAT(7I6)
  10  CONTINUE
      STOP
      END
//GO.FT01F001 DD UNIT=TAPE9,DISP=(OLD,PASS),LABEL=(1,BLP,,IN),
//  DCB=(OPTCD=Q,RECFM=FB,LRECL=25,BLKSIZE=5000,DEN=4),
//  VOL=SER=OUXXX
/*
//
```

Tape Description for the July 1989 1° x 1°
Ohio State University Data Set

Transmitted Tape identification:_______
Data tape created:_________

The tape contains a copy of the 1° x 1° mean free-air anomalies and related quantities of the OSU July 1989 data update. The file that has been copied was originally written on tape GS322, file 14, with DSN = TERR.ONEDEG.TUG87.JULY2189.

The file consists of 180 latitude records, with each record followed by 360 records, each containing 6 values. The first record starts with a latitude of 90° and the last record has a latitude (north west corner) of -89°. For each latitude, information is given for each 1° x 1° anomaly starting from (western edge) $\lambda = 0°$ and ending with $\lambda = 359°$.

The first value in a cell record is the latitude of the north edge followed by the following six values for each (0° to 359°) longitude:

1. Longitude (west edge of cell)
2. Code of evaluation
3. Free-air anomaly in mgal.
4. Standard deviation of the anomaly in mgal
5. Mean elevation based on the TUG87 model in meters
6. Source Code

The anomaly values are given with respect to the Gravity Formula of the Geodetic Reference System 1967. The code of evaluation relates to the procedure for estimating the anomaly. A complete list of codes is found in the report by Kim and Rapp (1989). If the code of evaluation is 15, the anomaly has been estimated through geophysical correlation techniques. The source code is an identification number that defines the source of data in this cell. The complete source list is found in Kim and Rapp (1989).

The latitude value is INTEGER*4 while all other values are INTEGER*2. The values are written formatted as follows:

latitude, I3
longitude, I3
code of evaluation, I4
anomaly, I4
standard deviation, I4
elevation, I6
source code, I4

When a quantity is not available the value is set to 9999. Information exists for 50,793 anomalies of which 5,672 have been estimated from geophysical correlation techniques.

The tape has been written at a density of _____ bpi. The record format is fixed blocked (FB) with a record length (LRECL) of 25 bytes with a blocksize (BLKSIZE) of 5000 bytes. The tape has been written in ASCII with by-pass label processing (BLP).

11/3/89